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ABSTRACT

Teaching notes for each of the 15 sections of the Scottish Integrated Science course, based upon the report of the Working Party on Secondary School Science (SE 015 432), have been written by teachers who taught the course in pilot stages. For each section there is a general introduction to the intent of the unit, a list of specific objectives, a discussion of the experiments contained in the Worksheets prepared by the Working Party (SE 015 434), and a short reference list. In many cases additional experiments are discussed and specific difficulties likely to be encountered by pupils are identified. Parts of the memoranda can be understood without reference to the worksheets or syllabus outline, but most experimental details are not repeated in the discussion of each section. (AL)

WORKING PARTY ON SECONDARY SCIENCE

INTEGRATED SCIENCE COURSE

Memoranda for Teachers
Sections 1-8 (Year 1)
Revised Version

Scottish Education Department

SED Working Party on Secondary Science

INTEGRATED SCIENCE COURSE

Memoranda for Teachers: Sections 1-8 (Year 1)

This set of memoranda offers guidance on the teaching of each section of the Integrated Science Course in some detail. The memoranda have been written mainly by practising teachers, experienced in teaching the syllabus at the pilot stages. It is hoped that their advice can help colleagues find their way through the course more easily and effectively.

The materials now available from the Working Party are:

1. Curriculum Paper No. 7 "Science for General Education", published by HMSO, including:
   a. Content of the Integrated Science Course suggested for the first cycle, Years I and II.
   b. Specific Objectives for each of the 15 sections.
   c. Specimen science topics for the second cycle.

2. Apparatus lists for Years I and II, which have been distributed directly to all secondary schools by SSSERC, the National Science Equipment Centre.

Ancillary Materials which have been distributed to all secondary schools by HMSO via Education Authority offices

3. Worksheets, for pupil use in Years I and II.

4. Objective Test Items, for Year I (Year II to follow).

5. Science Topics for Years III and IV non-SCE Courses, 18 "Brunton" Topics (12 more to follow).

6. This present publication, *Memoranda* for sections 1-8, Year I.

7. Memoranda for sections 9-14, Year II.

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The teaching notes given here have been provided by many different people and the Working Party would like to express its gratitude to them for the help they have given. It is not possible to name all who have submitted material but major contributions have come from the following.

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Mr J McClune	St Aelreds Secondary School Paisley
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Sister M Julie	Notre Dame High School Glasgow
Mr A W J Brooks	Science Adviser Fife Education Committee
Miss A Simpson	Paisley Grammar School

Members of the Working Party have also contributed along with HMII.
The Working Party is listed on page 2 of Curriculum Paper 7

GENERAL BACKGROUND THEORY ON EDUCATIONAL OBJECTIVES

1. J Bruner: The Process of Education, Harvard University
2. R Tyler: Basic Principles of Curriculum and Instruction, Chicago University
3. B Bloom: Taxonomy of Educational Objectives I + II, Longmans
4. R Mager: Preparing Instructional Objectives, ESL
5. J Houston: Principles of Objective Testing in Physics, Heinemann
6. W Hedges: Testing and Evaluation for the Sciences, Wadsworth, California.
7. R Mager: Developing Attitude towards Leaming, ESL

SECTION 1 - INTRODUCING SCIENCE

I Introduction

The intention of this section is, above all, to create interest in and enthusiasm for the study of science. The approach should not be from the standpoint of a formal treatment of length, area, volume, mass, density .... These ideas are certainly introduced, and it is expected that pupils will learn something about the means used to measure them, but they should be considered through a large number of experimental problem situations so that pupils may experience the satisfaction which results from solving the problems set.

II Specific Objectives Pupils should acquire

1. knowledge of (ie ability to recall) the use of measurement devices and units frequently employed in the sciences
2. the knowledge that there is considerable variation within any one kind of organism
3. ability to observe and record results
4. some ability to analyse certain data and draw tentative conclusions
5. awareness that human senses are limited and unreliable
6. awareness that some variables have distributions which are random and some which are non-random
7. awareness of the incompleteness of much scientific knowledge (black box)
8. INTEREST IN AND ENTHUSIASM FOR SCIENCE
9. confidence in handling simple apparatus
10. certain simple experimental skills useful in the laboratory

Achieving the interest and enthusiasm desired involves maintaining the delicate balance between establishing the discipline necessary for working in a laboratory and at the same time nurturing the enthusiasm with which these young pupils come to Science. The solution offered by the syllabus is the division of the section into *1.1 Pupil Experiments (P) and 1.2 Stations Experiments (S).* The first of these ensures the safety of the pupil by organising experiments in which all do the same thing. The second uses this experience and allows the pupils greater freedom in circulating from one station to the next, in small groups. These experiments are designed towards objective 8 mainly. If knowledge is gained by lecture techniques or skills acquired by excessive drilling, at the expense of enthusiasm, then this knowledge and these skills have been bought at too heavy a price.

III **Experimental details**

Notes on Experiments in Worksheets

Section 1.1 Laboratory Techniques

1. Handling solutions

125 x 13 mm test tubes can be used and the chemicals, approximately 0.01M, should be supplied, one set per two pupils, in small plastic dropper bottles. Instead of dropper bottles, ordinary bottles could be used and one teat-pipette should be washed with water before using for another solution. The latter method is convenient where reagents are permanently on a rack on the bench. The "example" experiment should be done first as a demonstration by the teacher so that the pupils all realise exactly what is required.

Time:- probably 2 periods since this will be done on the first day in the laboratory and time will be required for the issue of folders, checking names etc. It must be emphasised, however, that this work is designed for the pupil's first visit to the laboratory.

2. Using thermometers

A set, for each group of pupils, of all the apparatus required for these experiments should be available on the bench at the start of the lesson (ie thermometer (Celcius), aluminium beaker, tripod stand, bunsen burner).

It is best to start with a demonstration of how to read a thermometer and a *short* discussion of the units (°C) that are to be used.

In experiment 6 different groups can use different low-melting substances. The results can then be brought together and tabulated. The point can be made that different substances have different melting points.

Time:- 2 periods.

3. Weighing and Measuring Volume

Butchart or similar, single pan, direct reading balances should be used and an initial demonstration of reading and setting up the balance saves much time during the lesson.

In experiment 2 a block of wood and a block of metal of nearly the same mass should be supplied. Since these need not be accurately made they can be made in the school.

In experiments 3 and 4 graduated plastic beakers can be used instead of measuring cylinders.

Time:- somewhat less than 2 periods.

4. Handling Chemicals

In experiment 1 pupils should be left to devise their own methods of separating chalk from water. Any apparatus they may require, within reason, should be given to them. This does not mean that they should be allowed to use only apparatus which will effectively separate the chalk and water but they should be discouraged from using equipment which is completely useless for the task in hand.

In experiment 2 use any two solutions which will provide an insoluble precipitate.

In experiment 3 the calcium must be clean and not oxidised.

Time:- 2 periods.

5. Timing

The work required in this case is self evident.

Time:- 1 period.

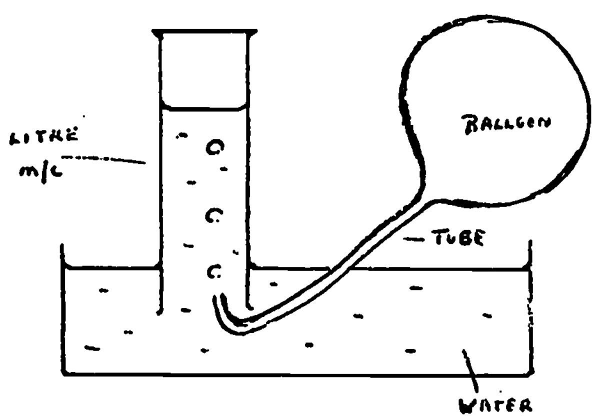
Section 1.2 Observing and Drawing Conclusions

Experiment 1 The apparatus consists of a microphone connected to the 'Y' input of a CRO. The timebase setting should be about the middle of the 1ms range (ie 200-300 Hz). A crystal micro phone will give sufficient input for direct connection to the CRO (SSSERC Bulletin No 40 gives details of a suitable type). To reduce 50 Hz mains pick up on the trace, screened cable should be used to connect the microphone to the oscilloscope.

Experiment 2 Include various metals and non-metals ensuring that among the metals are iron, cobalt and nickel. These are the best stored in a tray with divisions (about 3cm x 3cm) with the name of each material appearing at the appropriate place.

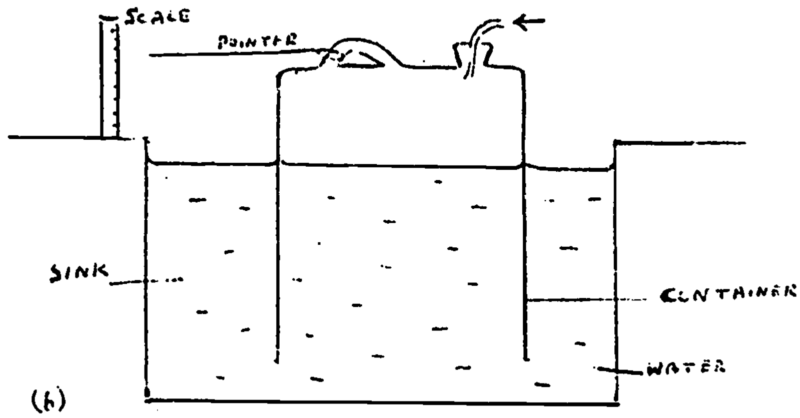
Experiment 3 Various methods are available for measuring the volumes of air expelled from the lungs. Two of these are:-

a. Blow up a balloon and then allow the air from the balloon to displace water from a large measuring cylinder. Note that several displacements are usually required for one lungful of air.



(a)

b. For this method a plastic two-gallon container has its bottom cut off and is immersed in water in a sink. It is essential to calibrate the apparatus and the container needs to be steadied using the handle to prevent it tilting over and releading air.

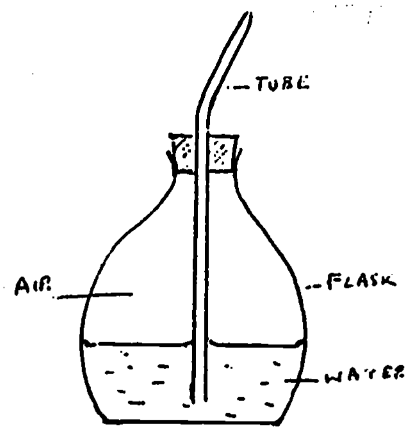


Experiment 4 Two plumber's force cups are used in a simplified form of Magdeburg Hemisphere experiment.

Experiment 5 The "metal rings" are ring magnets which are polarised on their flat surfaces. (Note: large magnets of this type can be obtained from old TV sets.)

Experiment 6 The rod is made of polythene and is rubbed with silk, flannel or, best of all, catskin. The jet of water from the tap must be small but not breaking into droplets and the rod must not be allowed to touch it.

Experiment 7 The bottle or flask used contains some water with a tube dipping into it.



Experiment 8 In this experiment six to eight small boxes (match boxes or typewriter ribbon boxes) are labelled A B C etc, and different small objects are placed in each (eg a pin, a piece of plasticene, a marble, a rubber). It is best if the boxes are sealed with sellotape or glued in some way. Pupils should not be told whether their deductions are correct.

Time:- for all experiments, 2-4 periods depending on the class.

Variation within one organism (3 sheets)

The information about the pupils should be used to build up a simple "key" of the type illustrated in the third sheet. This is best done under the supervision of the teacher.

Time:- 3 periods, with the possibility of the leaves being a homework exercise.

IV References

Curriculum Paper No 4 "Going Metric". Implications for Primary Schools.

Curriculum Paper No 5 "Going Metric". Implications for Secondary Schools.

Both are publiched by HMSO.

SECTION 2 - LOOKING AT LIVING THINGS

I Introduction

This short section develops the work begun in Section 1.2 and the suggested time allocation of 12 periods is an indication of the depth of content involved. Possibly Section 2.1 merits 3 x 2 periods and the same time could be given to 2.2 with 2.3.

It is important to remember that "Nothing complicated is envisaged at this stage" and that the main teaching difficulty will be to know when to stop. The broad aims of this section are:

1. to encourage the pupils to observe in detail one living organism and to discover something of its normal behaviour;
2. to develop 1. into a long-term investigation;
3. to formulate a hypothesis on the behaviour of certain living organisms and to test it experimentally;
4. to give an idea of the immense variety of living organisms and the need for classifying them into groups.

II Specific Objectives Pupils should acquire

1. the knowledge that animals react to external stimuli
2. the knowledge that there is a very large variety of living things
3. the knowledge that living things can be classified as animals and plants and that these can be further divided into sub-sets
4. some familiarity with the methods of constructing a simple key
5. some ability to observe objectively, this time in changing situations over longer periods of time
6. some familiarity with the formation of hypotheses concerning animals and ability to test these hypotheses experimentally
7. some familiarity with ways of analysing a complex of information to identify common elements (preparation and use of key)
8. a sense of wonder at the wide variety of living things
9. some simple biological experimental skills

III Experimental Details

As a preliminary to practical work it is advisable to follow up Objective No 9 - acquiring "Some simple biological skills" - with a demonstration of the correct use of a hand lens. Good results can be obtained only by using a *good* hand lens, - magnifying at least 8 diameters and preferably 10, and, at the same time, giving a flat field about 5 mm with sharp definition all over. The single lenses listed in the SSSERC Biology and Integrated Science apparatus lists are very satisfactory; most school suppliers have similar types. There is a right and wrong way to use a hand lens and, unfortunately, some Biology texts do not indicate the correct method.

The object to be examined should be brought by finger and thumb, forceps or test-tube to within 10-15 cm of the eye. Using the other hand, the lens should be introduced between the object and the eye, with the two hands just touching. The lens should then be moved slowly to and fro until the point is found at which the part of the specimen to be examined is in sharp focus. The touching of the hands give steadiness all round and makes the inspection much easier. The preference to close one eye is a personal one but using the best of the prevailing light is an obvious requirement.

Section 2.1 A Living Organism

In the worksheets, the earthworm has been chosen as the common living organism, for obvious reasons of local occurrence and the reference in many text-books, but it is possible to use any common animal collected from the vicinity of the school. Practical work should include

1. structure
2. movement
3. habits
4. environment - provided in miniature in the laboratory.

The external structure of the earthworm can be difficult to see and there is considerable variation in individual earthworms as to size and ease of observation - it is, of course, important to remember that there are different *kinds* (species) of earthworms. If the teacher is uncertain of the structure of the earthworm, reference should be made to a textbook eg Chapter 8 of Alan Dale's "Patterns of Life".

Worms may, of course, be kept in any soil-filled container providing that the soil is kept moist and the worms are fed with decaying vegetation. Layers of soil, sand and chalk can be arranged in the wormery and their position marked on the glass. The ploughing activities of the worms in making their burrows will alter these levels considerably. Black paper stuck on to one half of the glass provides a dark area for the worms, and it will be seen that most of the burrows are made near the glass on this side. Quantitative records must be kept of the number of worms and their feeding habits, based on surface feeding of a known number of "fallen" leaves or potato cubes, made of neat 1 cm cubes.

Worms will become inactive and eventually die if the soil temperature rises above 18°C. This can happen in most centrally heated laboratories, particularly when the thin Rothamsted-type wormeries are used. It is best, therefore, to store the wormeries in a suitable place outside the laboratory when they are not being observed.

It is possible to carry out this practical work with a variety of organisms but this will involve the teacher in preparing his own worksheets, and this can only be done with the particular animal in front of him. Snails, crabs, beetles, caterpillars are suitable animals and some questions on the last example are:

Watch a caterpillar feeding

1. What shape is the slice it takes out of the leaf.
2. In which direction does it move its jaws? Up and down or from right to left?
3. In which direction does it move its head while it eats?
4. How do the legs on the first three segments of the body differ from those further back, which are distinguished as claspers?
5. If your caterpillar is green and has no hairs you can see its heart beating all along its back. In which direction does it drive the blood? What colour is the blood? (Do *not* prick the animal, you can see the blood through the skin.)

   On a smooth caterpillar notice the little oval or circular holes in most of these segments, one on each side. What are these for? [These are the breathing holes.]

Further questions can be added on number of segments without breathing holes, what happens on touching the caterpillar, is it smooth or hairy, what uses are the hairs (some can pierce human skin and cause inflammation!)

Groups of pupils can work on different organisms, and class work can be combined records built up over a year's work. Pupils' records should be of a simple kind based on outline drawings of the animal to show the main structural features. At the beginning of this section reference was made to testing some simple hypothesis, and the sequence for the pupil could be as follows, for example, on movement or feeding habits of an animal:

1. observe closely;
2. record, by diagram or notes, what you have seen;
3. make a suggestion or *hypothesis* about *how* and *why*;
4. set up an *experiment* to test this suggestion;
5. note down the result;
6. does it lead to another hypothesis?

Here is an actual example - we observed that earthworms make casts on soil and that they pull leaves under the soil; the hypothesis is that all earthworms make casts; we set up 2 boxes of soil with a known number of a different kind of earthworm in each and placed a number of fallen leaves on the soil surface - result? An equally interesting sequence of Observation, Hypothesis, Experiment and Result can be developed from the O - earthworms have bristles on the underside.

It is important that class work should be organised in such a way as to allow for occasional observations on these biological investigations to extend between three and four weeks.

Section 2.2 Diversity of form

The worksheet No 5, headed Differences of form, might be the basis of a homework exercise with the pupils asked to bring in living material for follow up in class. The teacher can organise a display of a variety of common plants and animals, with the emphasis on living and the helpful criterion of the organism's ability to survive under laboratory conditions. The display can be extended using illustrations - the BBC schools booklets provide excellent ones - and possibly the attraction of a few "oddities" from sea-horses to "stuffed" alligators and hippopotami skulls (the latter do exist in at least one Scottish school). The smaller items can be placed in trays for easy handling and movement from class to class or class to temporary storage.

The original lay-out of the display should be unnamed and mixed, but each unit could be labelled with a number and the class asked to place these members in related groups. A limited amount might be given on the numbers of living organisms using the pie-chart idea as illustrated on page 11 of Text Book I of the Nuffield Biology Text. A wall display on conservation could be related to this teaching.

Section 2.3 Classification

This huge variety of living organisms must be organised into one orderly system. The analogy of stamp collecting can be involved as it allows the opportunity to look for a number of distinctive characteristics, viz countries, shape, colours, values etc. Sheets Nos 6, 7, 8, and 9 encourage different ways of making a classification, and it should be emphasized that classification is a convenience to help our study of plants and animals and is not an end in itself.

A practical outcome of classification is that we can use "keys" to identify plants and animals unknown to us. One design of a key is given on the tenth sheet in Section 1, but the form of the key can vary and examples are to be found in many natural history handbooks. However, they are difficult to use until a good deal of information on plant and animal structure is known by the pupils. At this stage it is only possible to use very simple keys.

As an exercise it should be possible to get the pupils to construct a key of their own et

1.	(Made at least partly of wood. (No wood at all.	3 2
2.	(Made entirely of metal, rather pointed at one end. (No metal present - rather soft to the touch.	PEN NIB RUBBER
3.	(Shape rectangular, with a moving lid. (Shape long and thin - no moving parts.	PENCIL BOX 4
4.	(Fitted with a metal holder at one end. (No metal at all	PENCILHOLDER PENCIL

Remember this key is supposed to tell us which one of five common objects we are examining, assuming that we do not know its name. "Animals with backbones" in Section 2 can be adapted to the form of such a key.

With young pupils it is easier to design a key based on easily observable differences for animals rather than plants. Dale's "Patterns of Life", from which the pencil case key is taken, covers a wide range of keys, and Chapter 2 on "Finding Names" gives advice on their construction. Keys will be used later in this Science course under Section 12.8.

Here is a simple key for animals with backbones.

1.	(Covered with hair, fur *OR* feathers. (Not covered with hair, fur *OR* feathers.	2 3
2.	(Covered with hair, fur or with whiskers on its body. (Covered with feathers.	MAMMALS BIRDS
3.	(Scaly skin (Moist, smooth, or warty skin.	4 FROGS OR TOADS
4.	(Hard scaly skin. (Wet scaly skin, fins.	SNAKES AND LIZARDS FISH

IV References

R A Clarke et al - "Biology by Inquiry" Book 1, published by Heinemann.

Nuffield Biology Text - Book 1 and Guide, published by Longmans-Penguin.

Alan Dale - "Patterns of Life", published by Heinemann.

SECTION 3 - ENERGY

I Introduction

The concept of energy is one which is so central to this syllabus and to later science courses that it was thought desirable to introduce it early. This will be found advantageous in later first year sections, such as 4 (Particles), 5 (Solutions) and 7 (Electricity). It has been found that pupils of all abilities react well to this section and to the sense of power which results from acquiring the ability to offer elementary explanations of many everyday phenomena in terms of the energy changes, mechanical→heat etc.

No attempt is made to define terms, to quantify, or to introduce units at this stage. In section 13 (Year II) the ideas will be sharpened to a certain extent, some measurements attempted and the joule introduced as a measure of *all* forms of energy.

II Specific Objectives Pupils should acquire

1. the knowledge that energy exists in many different forms
2. the knowledge that the different forms of energy are inter-convertible
3. the knowledge that foods provide the energy for growth, reproduction and movement in living things
4. the knowledge that food is essentially complex material, always containing carbon
5. awareness that energy can only be defined operationally
6. awareness of the finite quantity of energy available to mankind
7. awareness of the need for control and efficient use of energy resources
8. motivation for subsequent studies in a syllabus all of which is concerned with the interrelationship of energy and matter
9. creative ability in model-making

III Experimentol Details

Section 3.1 Forms of Energy

The pupil of today already knows many of the forms of energy. These should be elicited with examples. A demonstration may be required to elucidate certain points, eg energy can be stored in a spring or in chemicals.

If the words "kinetic" and "potential" should prove too difficult for certain pupils then the alternative forms of "stored energy" and "energy of motion" could be used. The time spent on 3.1 should not exceed 20 minutes.

Section 3.2 Energy Interconversions

This section introduces the pupil to the wide range of energy changes which exist and asks them to analyse each change, noting the form of energy put into the situation and the form of energy released.

The experiments listed on the worksheets are not by any means the only experiments which could be carried out, nor need they be the ones used by each and every teacher. Local situation might well offer more suitable appartus or different conditions. Nevertheless, much of the apparatus required will be restricted in quantity in any school, and it is, therefore, suggested that the best way of employing what is available is to lay out as many experiments as possible at different "stations" around the room and let the pupils move from one to another until all, or the majority, of the experiments are completed.

It must be emphasised that the energy changes noted by pupils may be simple or complex depending on the point of view of the pupil carrying out the experiment, eg in an experiment with a series circuit comprising an accumulator, bulb and switch, the energy changes could be listed in any of the following forms:-

a. Electrical→Light
b. Electrical→Light and Heat
c. Chemical→Electrical→Light and Heat

Allowance for this must be made when discussing each group's answers at the end of the experimental session, and the degree of sophistication in the answer will depend largely on the pupil's imagination and background knowledge.

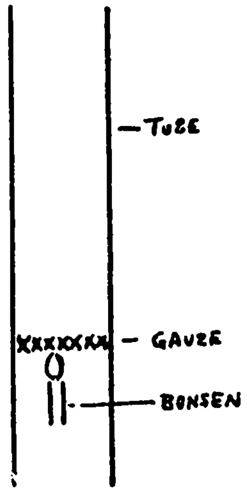
Notes on Experiments in Worksheets

Section 3.2

2. "Hold the tube over a bunsen flame and then remove it."

This is a startling demonstration of the conversion of heat energy to sound energy and is well worth doing.

The apparatus consists of a tube of any diameter and length (best results being obtained with an old cast iron drain pipe about 8-10 cm in diameter and about 1 m long). Into one end is fitted a piece of wire guaze to fill the cross-section of the tube completely. (In the case of the drain pipe this should be about 20 to 30 cm from the bottom.) The gauze is heated with a bunsen flame and, on cooling, the pipe emits ear-piercing notes.



5. "Wrap a match head in metal foil, place on a file with the head over the edge, and heat the head."

The metal foil should be thin, eg baking foil, and should be wrapped tightly round the match head.

11. "Close the switch in a circuit made up of an accumulator and a coil of wire."

The circuit consists of an accumulator, a key and a small coil of wire in series. The coil should be made of 7-10 cm of 32 SWG nichrome wire which has been wrapped round a piece of 4 mm rod to give shape.

12. "Put the junction of the wires in the bunsen flame and watch the instrument."

This consists of a thermocouple connected to a galvanometer. A suitable thermocouple can be made by interweaving a piece of copper wire and a piece of iron wire at one end.

13. "Switch on the electric motor."

Use a small, mains driven, electric motor.

17. "Hold a small piece of magnesium ribbon in tongs and heat the end in a bunsen flame. (Do not look directly at the flame.)"

Care should be taken with this experiment. Some teachers may prefer to do this as a demonstration.

18. "Uncover the photo cell."

Use a photovoltaic cell connected to a galvanometer, or a camera photometer.

Time for this section - 3 periods.

Section 3.3 Energy Converters in Action

This section is designed to show by models many every-day energy transformations. A most successful way in which this can be carried out is by using a Malvern Energy Conversion Kit. A number of the items of the Kit must be duplicated in order that the 10-14 experiments of the section can be worked using the "stations" technique. Many of these duplicate items (such as water turbine, bulb boards, drive shafts) can be made by laboratory technicians. Dynamo generators, purchased locally for a few shillings, can also be mounted on a piece of block board.

Notes on experiments in Worksheets

Section 3.3

2. "Switch on the motor until the weight comes up to the axle, then switch off. What energy changes take place?"

Disconnect the motor from the axle before allowing the weight to drop, otherwise most of the energy is used in the motor and not in hammering in the nail.

5. "Put the 2 way switch to the left and run the motor until the flywheel builds up speed."

Before commencing the practical session, *make sure that* everyone in the class is quite clear about which part of the circuit is connected and which part is disconnected when the switch is changed over.

10. "Switch on the motor so that the weight is lifted up off the floor. When it gets NEAR to the pulley, put the switch over the other way and watch the bulbs."

Same comment as on experiment 5.

Time for this section - 3 periods.

The same apparatus can be linked in many ways to show different energy interconversions. This provides an opportunity for the teacher to design a number of new experiments which can then be presented to the class, either individually or in a group, as a practical test of the work of this section.

Section 3.4 Energy and Living Things

Some of the most important energy interconversions are those which occur in nature. These should be discussed in the class to show that energy is involved in feeding, growth and reproduction. However, it is not necessary at this point to elaborate the process of respiration other than to mention it is an essential part of the release of energy from food.

Time for this section - 1 period.

N.B. As a final note, it will be appreciated from the above that it is NOT intended that this section develop the concept of machines and their uses, nor of energy measurement and its definition. The aim is to give an appreciation that energy exists in many forms and that it is possible to change energy from one form to another and store it for some future use.

IV References

Energy Conversions Kit

See:

a. Nuffield Physics Guide to Experiments, Book II, Experiments 61, 1-29

b. Esso-Nuffield film for Science Teachers, "Kinetic Energy; Introductory Experiments", one of a series of teachers' films available free of charge from

Travelling Films Limited
78 Victoria Road
Surbiton
Surrey

(see SED Science Newsletter No 6, page 24).

c. Physics is Fun and Teachers' Guide, Book I, Chapter 13 (pages 117-128), Jardine, Heinemann.

d. SSSERC Bulletins 5, 8, 24, 25, 27.

13

SECTION 4 - MATTER AS PARTICLES

I Introduction

In section 4.1 pupils should realise that observation is fundamental to the progress of scientific thought, and that the work of the scientist is to look at phenomena and then attempt to explain them. The explanation, which is a necessary part of scientific thinking, can never be as certain as the observations themselves.

It would be easy enough to accept the view, probably held by all the pupils, that matter is particulate, without further investigation. To do this would, however, be to sacrifice the opportunity of introducing scientific method. It is thought that pupils can understand the place of observation, hypothesis and theory in science even at this early stage, and it is, therefore, suggested that they should be confronted with a number of observations and then asked how they could explain them. They should come to realise that the only reasonable way of explaining them is to *suppose* that matter is particulate. The experiments are a selection only of many that the teacher might devise for this purpose, and he is of course, free to use any he may think useful. It is necessary to ensure that the pupil understands that the concept of the atom is purely an idea of a guess, and that no-one has ever seen an atom or ever will, but that it is a very good guess because not only does it explain all observed phenomena, but it has been successfully used to predict certain possibilities and these have always turned out to be correct. The part played by intuition in proposing hypotheses should be pointed out.

Section 4.2 is essentially information. It extends the particulate theory to the more specific concept of elements and compounds, and reintroduces energy as an essential, in the interaction of particles. The opportunity is taken to extend vocabulary so that correct terms, such as atom and molecule, element and compound and used. Although no recall of strict definition of these terms is required at this introductory stage.

Section 4.3 extends the involvement of energy still further to explain the differences of properties observed in the different states of matter.

In 4.4 certain properties explained by the kinetic theory are presented to pupils to provide opportunity for predicting from theory and having these predictions confirmed by the observed behaviour. The most obvious properties, relative weight, expansion and pressure have been chosen for this purpose. While the information obtained by pupils is clearly useful to them, it should be stressed that the major function of this part of the work is to give them experience of one of the major scientific methods, viz the use of the inductive method to formulate a theory and the testing of this theory by prediction, followed by experimental verification.

II Specific Objectives Pupils should acquire

1. the knowledge that there are 3 states of matter, solid, liquid and gas
2. the knowledge that matter is made up of discrete particles
3. the knowledge that the particles are in a state of motion
4. knowledge of a model of the states of matter using kinetic theory
5. knowledge of certain facts about some properties of matter) Section 4.4
6. information about some instruments)
7. knowledge of the use of the words element, atom, compound, molecule
8. some elementary information about the periodic table
9. some familiarity with the process of reasoning inductively, in constructing a kinetic model, and of testing the predictions from the model experimentally
10. ability to predict behaviour of matter using a kinetic model and to test the predictions experimentally
11. awareness of involvement of energy in making and breaking compounds
12. some simple experimental techniques

III Experimental details

Section 4.1 Fine division of matter

The section opens with a general look at solids, liquids and gases. Pupils are asked to give some example of these, and the general nature of these states of water should be discussed without giving definitions. It is good enough to say, for example, that a solid "stays put", a liquid can flow, and a gas flows even more easily and will be found throughout any space in which it is placed. Very little time need be spent on this. About five minutes is sufficient to ensure that the pupils have grasped the concept.

Not all gases are colourless, and it is interesting for the pupils to become acquainted with coloured gases such as nitrogen dioxide or iodine vapour. The work-sheet suggests that the pupils should experiment with the former. There is no need to name the gas.

The remainder of 4.1 is devoted to experiments from which the pupils should arrive at the conclusion that the best explanation of their observations is that matter is particulate. It is suggested that the approach is more easily made through a study of the behaviour of gases than from other states of matter, but this is entirely a matter of choice for the teacher.

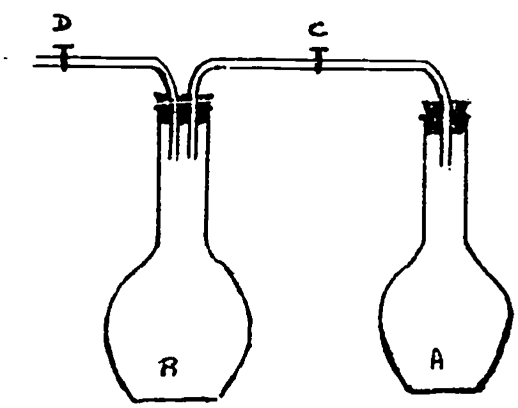
On studying the diffusion of gases from balloons it is desirable to choose gases of widely different densities, hydrogen and air, coal gas and air, or air and carbon dioxide. The balloons used should be of the same material. Balloons can be inflated with air, hydrogen, coal gas, carbon dioxide etc by using a hand bellow which has a valve at each end. In the case of hydrogen or other gas prepared by chemical action the rate of pumping should be according to rate of production of the gas. Carbon dioxide can be safely obtained from a cylinder but the use of hydrogen cylinders in schools is discouraged. Both balloons should be filled to the same size, and securely tied at the neck. After a few hours the balloon containing the less dense gas will have shrivelled more than the other.

The pupils should be asked for a reasonable explanation. They will probably suggest the existence of pores in the rubber. How could they find out if this were so? Experiment soon shows that there can be no pores as we usually know them. Nevertheless the balloon seems to act as a sieve. How can it do this? Only if there are, in fact, very minute pores and the gas itself is made up of very tiny particles. *The pupils should be able to supply these guesses.* They should not be handed out to them by the teacher.

Some pupils should be expected to suggest the variables in this experiment - the balloons, same material, blown up to the same size, same environment.

In a further study of diffusion a drop of bromine (caution) is put at the bottom of a flask by means of a thistle funnel, the funnel is withdrawn and the flask stoppered. Soon the colour of the bromine fills the flask. Liquid nitrogen dioxide (prepared by heating lead nitrate and condensing the netrogen dioxide in a U-tube placed in a freezing mixture) can be used instead of bromine, but it too is a dangerous substance.

The difference in the rate of diffusion of bromine in air and that in a vacuum should next be demonstrated. Two flasks are connected by a tube with a tap.



A drop of bromine is placed in flask A, the apparatus is assembled and tap C is closed. Flask B is then evacuated and tap D is closed. [It is not necessary to have a very good vacuum.] Tap C is then opened, when immediately the brown colour of bromine appears in flask B.

Ask the pupils why diffusion is so much faster this time.

After these experiments with gases we pass to diffusion of liquids through liquids. A crystal of copper sulphate is placed at the foot of a gas jar and is covered with water. The copper sulphate dissolves and the solution slowly diffuses through the water. Other coloured soluble substances can be used instead of copper sulphate. Ask the pupils if the speed of diffusion of solution through water is greater or less than that of a gas through a gas. Can you explain the difference? If so, why? What conditions are necessary for reproducible results?

The diffusion of substances through gels can then be set up. A petri dish is filled with agar which is allowed to set. A crystal of copper sulphate is placed on it. Diffusion occurs in all directions. The experiment can also be carried out in a test-tube. It is easy to devise variants. Pupils might object that the effect is due to gravity; they should be encouraged to do so and to explain how they could find out. It is easily possible to arrange for diffusion upwards, by turning the tube upside down. Is the rate of diffusion through a gel faster or slower than through water? Can we guess why there is a difference?

The gradual loss of colour, as a solution of potassium permanganate is progressively diluted, is next examined. How is this explained?

A very small drop of oil placed on water in a large trough spreads out and covers an approximately circular patch. (See Nuffield Physics Guide to Experiments I, experiment 67.) The surface of the water is dusted with dust to show up the oil patch. Ask why there is a limit to the size of the film. How could be test our guess?

The pupils mix 50 ml alcohol and 50 mi water, and find total volume (after cooling). Why is it not 100 ml?

Ask how we could try a similar experiment with salt and water. Can we measure out a certain volume of salt and dissolve it in a measured volume of water? What about powdering the salt? Can we do this well enough? Is there any other way? Add salt to a beaker full of water. Some salt can be dissolved without the water running over. [This is not a particularly good experiment for our purposes because surface effects can to some extent explain the result.]

The fact that very thin layers of metals, such as gold leaf or Dutch metal or mylar sheet, and transparent can be shown by mounting the metal between glass plates and either holding them up to a source of light or using a projector.

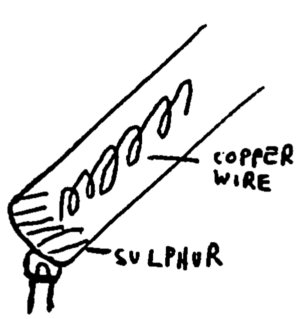
The Brownian movement is shown with a smoke cell or by using a suspension of Indian ink or poster paint on a small cell on a microscope slide. It must be illuminated horizontally. The pupils should see bright specks of light vibrating. They do not move very far. How can this be explained? By this time pupils will have gathered enough evidence for the particulate theory and they will probably think that in the Brownian movement they are actually seeing molecules. They must be thoroughly disabused of this idea. Analogies such as the movement of a large beach ball pushed by a host of small boys may bring this home. [Unfortunately the analogy of a football is not very good as a *small* ball is being pushed about by *large* people; the Brownian movement is the converse of this.]

SSSERC Bulletin 33 gives details of a model where large polystyrene spheres are pushed around by small ball bearings.

It is not necessary for all pupils to do all these experiments but they should all be done by different groups and the results fully discussed. As stated in the opening paragraphs of this memorandum it is essential to make the point that the atomic theory is a guess to explain the behaviour of matter, but it is a very good guess.

Section 4.2 Structure of Matter

We ask the question: what happens when things are mixed? Sometimes nothing; sometimes everything!



A little sulphur is placed at the foot of a hard glass tube, and a coil of fine copper wire is inserted into the tube above it. When the sulphur is heated (care! pupils have not had much experience) it vaporises and comes into contact with the copper, the latter glows red. The product can be withdrawn from the tube and examined. It is clearly very different from copper. Where has the sulphur gone? [There are, of course, other ways of doing this experiment; and iron can be used instead of copper.] Emphasise that the copper got *red hot* although it was not heated. Where could this energy have come from? Show the class copper sulphide from the bottle.

Show the formation of copper chloride by putting a piece of red hot copper foil into a gas jar of chlorine gas.

Let the pupils electrolyse the solution of copper chloride with carbon electrodes. Show the deposition of copper and liberation of chlorine. Here we have made a new substance - and energy was given out, and we have broken it up again by putting energy in. We can now discuss the difference between elements and compounds and introduce the terms atom and molecule, dealing with compound formation as an interaction

between atoms. [At this stage there is no need to deal with sub-atomic particles.] It is not necessary to define these words in detail; if the pupil understands the terms and knows how to use them correctly that is all that is wanted.

Pupils may be introduced to the periodic table as a means of classifying the element, and the use of symbols for the names of elements can be explained. They should not, however, be made to *learn* the table, or the meaning of the symbols. This will come later on through repeated use.

There is no particular point in distinguishing between physical and chemical change; in fact the distinction is often artificial and confusing.

Section 4.3 Kinetic theory

We have now devised a theory about the nature of matter, which clearly fits in with chemical action. How can it predict other properties of matter and are these predictions, in fact, true?

In the course of section 4.1 we came across observations which seemed to suggest that the particles which make up matter are moving and are closer in solids and liquids than in gases. That a small piece of solid CO_2 gives a large volume of gas can be demonstrated by putting some into a balloon and tying the neck. As the solid CO_2 changes to gas the balloon swells up.

[The fact that a little water gives a lot of steam might come out; a kettle full of water gives a room full of steam, but it must be remembered that the "steam" we see is a lot of globules of liquid water. It is best to steer clear of this one; the CO_2 experiment was used to avoid this pitfall.]

We can explain all the properties of matter by using the molecular model. In a solid the particles are compact, usually arranged in ranks and files, or in layers or in spirals or some other simple geometrical form. They are very "ordered". In a liquid the particles are more free to move, they are generally somewhat further apart and are less "ordered" than in a solid. In a gas the particles are much further apart and are "disordered".

[It is well to use the idea of "order" and "disorder" at this stage; the pupils understand it, and these ideas will be useful later on.]

The difference between solid, liquid and gas can now be illustrated in kinetic terms by means of one of the mechanised models now available [eg beads on a vibrating loud speaker cone]. Again it is important to distinguish between this crude model and actual molecules.

Section 4.4 Applicotions

The fact that some substances are "heavier" than others is obvious when we think of lead or copper sinking in water, or gases bubbling through water. A few simple experiments should be carried out to illustrate this.

That the word "heavier" is not good enough in this context is easily shown by pointing out that it does not matter how much water we have, copper still sinks in it. Obviously the water can be very much heavier than the copper. Hence introduce the need for a more correct term - ie relative weight. This term is used in preference to density, because the latter seems to evoke in the minds of some science teachers the performance of an interminable series of experiments and subsequent problems on density determinations. Provided the teacher steers clear of this temptation there is no reason why he should not use the term "density". At this stage there is no need to determine any densities at all, but values might be given from books, including those of gases, usually ignored.

What would we expect to happen when energy is put into a collection of particles, ie when they are heated? The pupils should arrive at the prediction that the collection would expand. Another possibility is that a solid might change into a liquid and a liquid into gas. Changes of state are dealt with in these terms in section 5, but if the teacher desires they could very well be considered here. Pupils when asked the question "What is likely to happen when a substance is heated?" will often answer "It will burn". If this arises we shall have to explain that this can only happen when two things are involved - viz the substance and air. At this state it is good enough to leave it at that.

The fact that solids, liquids, and gases expand on heating is, therefore, next discovered. The usual experiments can serve here - bar and gauge, compound bar (best with one strip of invar) breaking a nail on contraction, expansion of liquids and gases. This section could well be covered by a "stations" technique, or by

sharing the results from different groups. The facts which the pupils should find out for themselves are:

1. Expansion on heating appears to be a general phenomenon. To discover this it is necessary that the apparatus used for examination of the phenomenon with solids should make use of as many different metals and substances as possible. In the past we have usually been satisfied with using two metals, say iron and copper, and then saying (and expecting the pupils to acquiesce) that all metals expand.

2. For metals the effect is very small.

3. Liquids expand more than metals.

4. Gases expand more than liquids.

The statements as they are made here are very bald and are not scientifically sound. In fact they are as bad as the misuse of the word "heavier" which we referred to above. Some pupils should be able to point out what is wrong with them.

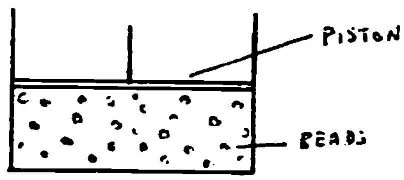
A simple explanation of these observations in terms of the particulate theory of matter can now be attempted. A fuller story in terms of inter-particle forces competing against thermal agitation must await a later cycle of development.

Everyday applications of expansion such as thermostats, fire alarms, removing "stuck" glass stoppers, sealing preserve jars, etc should be mentioned, and pupils could be encouraged to make models of some appliances making use of expansion.

Another property of matter which we can usefully introduce here is compressibility. This time we could ask the class to predict from the model what the order of compressibility would be. There is no ready way of comparing the compressibilities of solids and liquids; in any case the model would lead us to believe that they are not easy to compress. On the other hand gases can easily be "squashed". Examples such as pumping air into a tyre, sitting on an air pillow, etc can be given. It can be pointed out that the fact that solids and liquids are so difficult to compress is one of the factors which makes them important. The transmission of force by a liquid can be quoted - as for example in hydraulic brakes.

This topic leads on naturally to the idea of pressure. The concept of pressure as a force spread over an area is easy to get at through pumping air into a bicycle or car tyre. All pupils are familiar with this. The explanation of pressure as due to the bombardment of a surface by moving particles can then be introduced by means of the kinetic model. The moving beads hit a cardboard piston and force it up.

In terms of the bicycle tyre, we force more particles into the tyre; hence the walls of the tyre will be hit more frequently and the pressure is greater.



The fact that air exerts pressure is then shown by the Magdeburg hemispheres (Plumber's force-cups) and the collapsing can experiment. This leads to two points:

1. The considerable pressure exerted by the air

2. Why does a can not collapse ordinarily with this pressure acting on it? This is a difficult one for young pupils, and can call forth some very searching questions. If we say that pressure acts equally in all directions, we should have, for example, on a glass tumbler forces inside and out of considerable magnitude. Why do they not crush the glass? If we think of the converse problem - forces on a rope putting it under tension - it is possible to break the rope if the forces are big enough. Yet provided we increase the pressure equally on all sides of a glass it does not matter how big the pressure is, the glass is unaffected. The teacher must be prepared for this kind of question to arise.

The collapsing can can serve as an introduction to a possible way of measuring pressure, and pupils may be able to construct a simple apparatus for measuring air pressure, based for instance on changes in the curvature of a rubber membrane stretched over a beaker. This leads on to the aneroid barometer.

It is possible that pupils may want to know how the aneroid barometer is calibrated, and this question may make the teacher consider the mercury barometer. With pupils who are progressing more quickly it is possibly a good idea to bring it in any case, with the others only if the matter arises.

The uses of the barometer in weather forecasting and as an altimeter should be dealt with.

The Bourdon gauge is a simple way of measuring pressure and should be shown in the form of a model with a party-toy analogy. How would you calibrate a Bourdon gauge is a question the faster pupils should now be able to answer.

Experiments with syringes can be used to show the transmission of pressure by gases and liquids, and questions such as "Why does the syringe fill when the plunger is raised?" should now receive an adequate answer.

IV References

SED Alternative Chemistry, Memorandum No 2

Nuffield Physics Guide to Experiments No I, published by Longmans-Penguin

For Section 4.1, Nuffield experiments 1, 2(a) 52-62, 67
For Section 4.2, Nuffield experiments 20(a), 49-51
For Section 4.4, Nuffield experiments 38, 43, 48.

Chemistry takes Shape and Teachers' Guide Book 1, Chapter 1, Johnstone and Morrison, Heinemann.

Physics is Fun and Teachers' Guide, Book I, Chapter 5, Jardine, Heinemann.

Questions in Physics, Chapter 2, Houston, Heinemann.

Smoke cell design - SSSERC Bulletin 4.

Thermal expansion model - SSSERC Bulletin 35.

SECTION 5 - SOLVENTS AND SOLUTIONS

I Introduction

In this section we study water, the things which will and will not dissolve in it. This leads us to consider other solvents and some things which may seem to be solutions but which in fact are not. In turn we are led to think about one of the most important solution processes of all - digestion. The intention is that some information of considerable importance should be acquired. At the same time, however, the content is an admirable vehicle for many of the other things the syllabus tries to do.

Four sections have normally been covered, and in these training has been given in observing, in theorising, and in designing experiments. Especially, the pupils will know about energy and the particulate nature of matter. With this in mind it is possible to frame the following objectives.

II Specific Objectives Pupils should acquire

1. knowledge of some facts about evaporation and cloud formation
2. knowledge of some facts about water purification
3. knowledge of some facts about solubility
4. knowledge of some facts about crystals
5. some information about solvents and extractions
6. some information about colloids
7. knowledge of some facts about digestion
8. knowledge of the use of control experiments in enzyme experiments
9. ability to form hypotheses concerning solubility and to test these experimentally
10. ability to design experiments concerning solubility
11. ability to work with multiple variables in these experiments
12. awareness of the need for patience in a long.term project (eg crystal-growing)
13. awareness of the need to conserve water and of the importance of water to man
14. skills in using some scientific techniques, eg crystallising, chromatography, emulsifying.

Eight of these objectives are about knowing. Care should be taken not to ask pupils to know too much. The fact is that they are still only twelve. It must also be remembered that there is little in this section which will not be looked at again before 'O' grade, and, certainly, what little is unique - the idea of colloids seems the only thing which might be necessarily recalled - is really given little emphasis at 'O' grade or beyond.

Objectives 9, 10, and 11 represent the most important aspect of this section. For the greater part of the time spent on this section, pupils should be designing their own little experiments to justify the various theories which they should be required to formulate. If this work is well presented, the bulk of the knowledge we hope pupils will gain, will be gained by usage rather than by specific instruction.

III Experimental Details

Section 5.1 Water Cycle

First Sheet - The Water Cycle

This is really an excuse to reinforce the ideas gained at the beginning of Section 4.1. If the idea of matter as particles is well understood it should be possible to explain evaporation, etc satisfactorily. Our pupils can then consider intelligently the conditions needed for evaporation.

Conditions for Evoporotion

These might well be discussed by the whole group, before worksheet 2 is given out. This is a multi-variable situation and the point must be made that only one condition at a time can be varied. Should pupils decide on a procedure different from that given, by all means let them follow it as long as the end result is the same. This work could well be seen as a verification of predictions from our understanding of the effects of energy on particles. This set of experiments is well worth spending some time on.

Cloud formation (Demonstration)

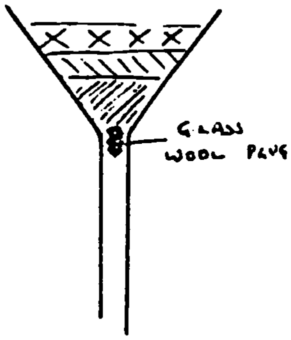
The cloud formation is an easy demonstration but is somewhat transient in nature. A winchester bottle is made moist by rinsing it out with some water. A bicycle pump is fitted to a tube in a rubber bung. The bung is placed lightly in the winchester and the pressure increased in the winchester until the stopper is

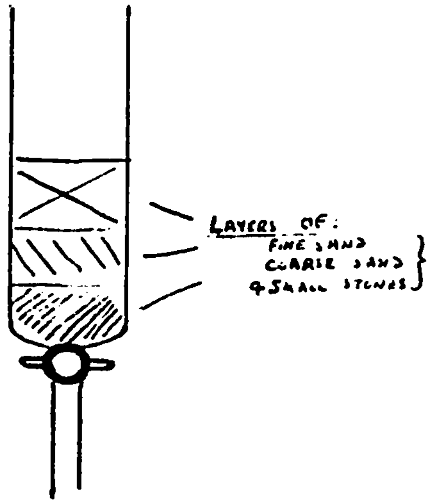
blown out. The sudden reduction in pressure causes a cloud to form for a second or two. Take care not to push the stopper in too tightly.

Purifying our water supply

To get a good starting sample ensure that both mud and weed are collected with the pond water. As an alternative allow baled hay to soak in muddy pond water for some weeks.

Ensure that the filter is not too efficient before allowing the class to use it.





These are alternative forms of filter.

The living material in the water is included to show the need for chlorination. To ensure their presence the sample should be taken from the bottom of the container. A drop of chlorine water of the slide is usually enough to kill off any life.

Sometimes the living material cannot be seen under the microscope. An alternative method is to pot agar plates with filtered water before and after chlorination. Two to three days incubation is enough to show the desired results. This can be followed by use of reference material to survey methods for obtaining drinking water.

Section 5.2 Solubility and its Uses

Growing Crystals

This is always popular and especially if results can be seen immediately. Super-saturate and put a drop on a microscope slide - watch it grow. Some discussion of natural crystals can be stimulated and cleavage shown. A model can be used to show cleavage planes. Some large crystals can be grown also, as a long-term project.

Non-aqueous solvents are included to show that water is not the only thing which dissolves. Stains are introduced to give some usefulness to the work. It is however only information-giving and should not be given much time.

Some work on separations should be undertaken, but, do not try to set these as problems rather than methods to be learned. Try to get pupils to think for themselves. The Section 5.2 Sheet on chromatographic methods is another method which they are not likely to know. Small spots are needed, and in the right place. Black inks are useful liquids since they are usually mixtures of red and green, or yellow and blue, solutions.

Section 5.3 Emulsions and Colloids

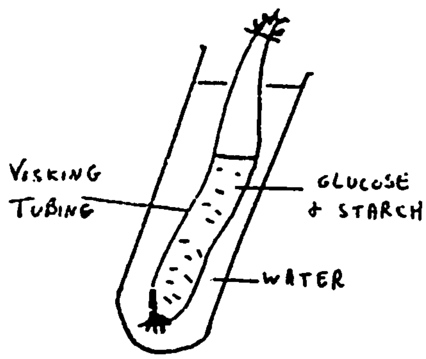
If we want to get into the subject of digestion it is good if we can look at colloids and emulsions first. This will also pose the teaser of the "solution" which is not a solution. Need for an emulsifying agent should be stressed. The other point is the size of particles which can scatter light (Tyndall effect). There is nothing difficult in this - but do not take it too far. A starch is easy to make. Add a little starch to a large

volume of boiling water. The sol should be quite clear on cooling. Another useful sol is colloidal iron (III) oxide. This is made by dispersing freshly precipitated iron (III) hydroxide in a concentrated solution of iron (III) chloride which is then dialysed. This should give a blood-red liquid.

Section 5.4 The Process of Digestion

The introduction to section 5.4 might involve the making of lists of food, to make the point that very few are water-soluble. The question must then be posed as to how food gets from the gut (ie still outside the body) into the tissues where it is needed. A simple diagram of the alimentary canal should be available but no details given at this stage, for the gut wall.

It is therefore necessary to carry out some preliminary demonstration of diffusion through visking tubing, to establish that, in a mixture of starch and glucose only glucose will pass through the walls of the tubing. The experiment is shown in the diagram.



Test for glucose with Clinistix; these are much easier to use than the conventional Benedict's or Fehling's Solutions. These should be given to pupils only as spot tests for glucose and need not even be named. The *soluble* glucose gets through; the *insoluble* starch does not. The visking tubing is here used as a model.

Be careful with visking tubing. This is a differentially permeable membrane and water will osmose into the tube at the same time as glucose diffuses out. Most pupils will not notice this if the experiments are completed in a reasonably short time. Do not overfill the tubing, and allow for gas escape, otherwise pressure effects may become obvious.

An alternative technique for using visking tubing is described in SSSERC Bulletin 18.

Digestion

About 10-20 per cent of all people have no ptyalin in their saliva, hence the need for at least two samples in the starch solution.

The role of the enzyme should be explained only in terms of breaking down the food into water soluble substances. No mention of catalysis should be made at this stage.

The function of the control experiment should be emphasised in this work.

Diastase may be used as an alternative to ptyalin. This can be purchased or extracted from barley by grinding germinating grains in a little water.

A final experiment to demonstrate both digestion and absorption can be shown using starch and saliva contained in visking tubing. In this case the two processes of breakdown and diffusion are shown together.

The starch solution should be more concentrated than in previous experiments - and watch the time here. It may have to be left for more than 2 periods.

IV References

1. Nuffield Background Books (Chemistry) Longmans/Penguin

   Detergents
   Colloids
   Water

Making Diamonds
Dissolving
The Structure of Substances
Growing Crystals

2. Crystals and Crystal Growing Holden and Singer Heinemann

3. Longman's Physics Topics. Series of background readers includes "Crystals", by Sister M Hurst.

SECTION 6 - CELLS AND REPRODUCTION

I Introduction

Some of the most interesting aspects of biological study are to be found in this section, which provides for a comprehensive study of cells but deals particularly with their organisation and function.

A wide variety of material is required for this section, and detailed advance planning and preparation will be necessary. Contact should be made as early as possible with sources of supply. These include parks' departments, marine biological stations, pet shops and biological supply firms. The ability of children to collect their own materials should be encouraged.

It is envisaged that Section 6 will be studied by pupils in SI. Many of the specimens required will only be available in the proper condition in the spring-summer months of the school year. This is an advantage in that the teacher will, by then, have had the necessary time to develop a personal knowledge of the members of his or her class. The headmaster will have had the opportunity to make known to the parents of these particular children, and to others concerned with their moral education, that a section of the work will be dealing, in some detail, with the biological facts concerning human reproduction. This will enable those parents who wish it to have a preliminary discussion with their children before lessons are given in the school. Perhaps it is at this stage in the secondary school that the topic can best be dealt with from a biological point of view. While most pupils will have entered puberty, they are still psychologically much more stable than they will be in a few years and can regard sex with a more objective attitude than they will be able to do when they have fully entered adolescence. To an increasing extent much of what is to be taught in this Section will be familiar to pupils as a result of the work done in the later stages of the primary school.

Many will hold it desirable to rearrange classes, if they are mixed, so that single sex groups or sets can be created. If it is impossible to do this for entire classes or for all of the work, it can at least be done for part of it so that pupils can discuss questions appropriate to their sex. Sets of well-illustrated booklets with text written for this age level should be available for private reading at home (eg Merrigan's "The Sixth Day": Darton, Longman and Todd)

Although this imparting of biological data cannot be equated with sexual education and the latter's involvement with moral principles, it cannot be entirely divorced from it and is, itself, an essential part of a sound factual basis for emotional and psychological growth to maturity. Therefore, the various persons concerned with these aspects of the child's education should be aware of each other's work.

II Specific Objectives Pupils should acquire

1. knowledge of the cell as a unit of structure in organisms
2. knowledge of the cell as a unit of reproduction in organisms
3. knowledge of the reproduction of cells and the replication of living material
4. some information on the methods of achieving fertilisation
5. knowledge of the concept of fertilisation
6. knowledge of the facts of mammalian reproduction
7. some information on cellular growth and the development of multicellular organisms
8. some information on methods of caring for young organisms
9. some information on the distribution of species within a population, eg dispersal experiments
10. ability to classify from observable characteristics, eg living and dead tissue, from observation on a series of preparation of cells
11. ability to compare and interpret differences in similar structures, eg in floral development or in development of chick embryo
12. an objective attitude to the facts of repreducation
13. an awareness of the continuity of living tissues from generation to generation
14. some skill in the use of the microscope in the study of cells

III Experimental Details

The contents of Section 6 fall into two parts:-

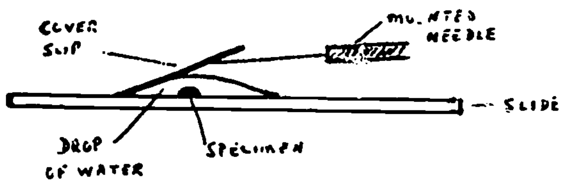
i The very simple structure of plant and animal cells as soon by simple microscopy;

ii the division of labour among cells and the nature of the specialised cells in the reproductive mechanism.

This is a well documented aspect of elementary biology, and references can be found in many textbooks.

The study of cells must involve the use of microscopes, and the choice of a suitable instrument for use by twelve-year-olds is important. The microscope must be simple, easy to use, inexpensive (to allow for the purchase of adequate number), and as nearly unbreakable as possible. There should be a reasonable magnification, clear resolution and a simple fucus adjustment. Several microscopes on the market fulfil these conditions and SSSERC should be consulted before ordering any particular model.

The correct use of the microscope should be demonstrated, it involves the names and functions of the main parts, adjustment for correct lighting, preparation and examination of the microscope slide preparation, and the method of focussing and changing magnification ("power"). It is not difficult to make a wet mount of a microscopic specimen, and after it has been demonstrated by the teacher the pupils should repeat it and record the exercise in their notebooks, perhaps as a simple diagram.



It is important to lower the cover-slip gently to avoid air bubbles, and practice will soon indicate the correct size of drop of water or other mounting liquid. Pupils should be reminded that, in looking at microscopic preparations of onion scale and rhubarb, the thinnest layer will give best results. The plant tissue should be pulled off with forceps. Remember! when obtaining cheek cells use a gently scrape and it is preferable to scrape the inside of the cheek with individual wooden toothpicks (broad end) or medical destructible spatulas rather than with the finger nail.

Section 6.1 Cells and living things

Pupils should have the experience of working with a microscope and seeing a variety of cells from different sources eg onion scales, cheek linings, the microscopic fauna and flora of pond scums and hay infusions. [Pond scums can be cultured in beakers in diffuse light but have a disconcerting habit of undergoing sudden changes in population. A hay infusion is easily made by placing some chopped hay in a slightly warm mixture of water and pond water; if left for a few days this should produce myriads of tiny one-celled organisms, most of them animals. If a good culture is produced with plenty of fast-moving organisms they can be slowed down by the addition of "polycell" 1:1 or by scattering small bits of filter paper on the slide.] It is important to show the variety of cells and their arrangements - some will be single cells, eg pollen grains or one-celled organisms; or single cells living in a bunch (in a colony), which may be permanent or more frequently temporary eg microscopic plants like the spherical pond-scums; or cells living together, ie tissues, of which onion, Canadian pond weed are examples. Blood is an example of tissue, but it requires very careful preparation as a microscopical mount and it is difficult for younger pupils to appreciate it as a tissue.

Pupils should grasp the universal fact that all living organisms are made up of tiny units called cells which consist of material called protoplasm, the activities of which we call "The Characteristics of Living Things". It is not necessary to go into the details of cell wall, cytoplasm, vacuole, etc, but pupils should see that living cells vary in size, shape and colour and that they all have a nucleus, which controls the life of the cell. It may be possible to see, in a mount of Canadian Pond weed, the movement (streaming) of protoplasm. The streaming may be stimulated, using warm water as a mounting liquid.

Cells can be stained, using iodine, which is lethal to them, or a vital dye which can stain living cells without killing them, neutral red being one of the most widely used. It is used as a drop of one per cent solution of the stain (made up in distilled water) to a tumberful of pond water - one drop of this final solution can be added to water on a microscope slide for staining a selected microscopic preparation. The result can give spectacular results on a preparation containing mobile, one-celled organisms. Janus green, Bismarck brown and methylene blue may also be used. All living things started life as a single cell, and reference should be made to our own origin as a fertilised egg cell, just within the limit of sight by the unaided eye (2" x 2" slides are available on sperm and eggs).

Detailed notes and diagrams on cellular structure should not be given. It is at the discretion of the teacher whether to deal with the difference between plants and animal cells, but if the spirit of the above approach is accepted the pupil may not necessarily be in personal possession of all the knowledge necessary for understanding the distinction

The pupil should however now be aware of one of the great principles of Biology - "Omnis cellula e cellula". It has the most far-reaching effect upon the study of biological phenomena.

Section 6.2 Role of cells in reproduction

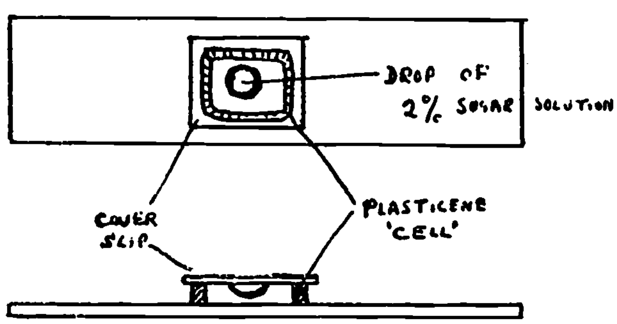
The introductory work will have given the idea of Division of Labour - ie the dividing up of jobs for different cells. In the microscopic preparations to date, some cells will have hairs (cilia) that cause the organism to move by lashing the water all together, while in some of the colonial pond scums, particularly the spherical ones, "daughter" ones may be seen inside the large ones. In a few animals and many plants reproduction is little more than extended growth ie some part of the organism breaks loose and continues its life as a separate individual. In some other cases, chiefly in plants eg ferns, mosses, fungi, and organism produces single cells which can grow after a period of rest into new organisms. Such cells, capable of developing by themselves into new organisms, are called spores.

Sexual reproduction normally involves the fusion of two cells.

The teaching approach should be simple, viz:-

1. Most plants and animals produce special cells for reproduction.
2. These cells are produced in special organs.
3. The reproductive cells alone cannot form a new individual but a male and female cell must unite.
4. There must be a method for the male cell to reach the female cell and fertilise it.
5. After fertilisation the new young plant or animal is protected in some way as it develops.

The work sheets deal first with flowering plants. Before starting on the detailed dissection of flowers, the basic structure should be understood. A variety of flowers should be used and a diagram built up, by blackboard or cardboard model, to illustrate floral structure and differences between wind and insect-pollinated flowers. The pupils' notes for this section should include a diagram to show the path of the pollen tube in growing towards the ovule. You can watch the beginning of this process by suspending pollen in a drop of two per cent sugar solution on a microscope slide. Invert the cover slip on a plasticene cell made on a glass slide. Observe under a microscope at intervals of 30 minutes to see the growth of the pollen grains.



The general position of the reproductive organs in macroscopic animals can be demonstrated with fish roes (the hot water dissections of a whiting - parboil it and use fingers and thumb:- can be a useful illustration of body arrangement) and with dissections of frogs or other vertebrates originally prepared by older classes. The pupils' records can include a very simple diagram of the human reproductive systems - a useful one is "Biology by Inquiry" book I, page 82, Figure 5.11. The path taken by the sperms to reach the egg can be shown from these diagrams. It is important for the pupils to grasp that the cells in the body of a plant or an animal are separated into two divisions, (1) the body cells, and (2) the germ cells.

Fertilisation is when the sperm cell enters the egg cell, which then begins to divide and start the development of a new individual.

It is possible to show fertilisation taking place, and information is to be found on this in "Biology by Inquiry" book 1, Chapter 5, or in the SED "Science News Letter", No 5, in the article on "The Teaching of

Embryology", and the two animals recommended for study are Pomatoceros and Rhabdites. Biological Suppliers can supply good Pomatoceros material if it cannot be collected in the vicinity of the school. (Bull sperm may be obtained from an A.I. centre. It can be transported in a thermos flask and used as a demonstration to show the continuous movement of sperms.)

Section 6.3 Methods

This section is concerned with how the male and female cells are brought together for fertilisation.

The pupils will have seen examples of wind-pollinated and insect-pollinated flowers and their attention should now be drawn to the large amounts of pollen in wind-pollinated flowers - this can easily be demonstrated by shaking a grass head. They should also appreciate, including a taste of it, the attraction of the nectar and bright colours in insect pollinated flowers. Brief mention should be made of self-pollination.

For animals, ample occasions to observe the reproductive behaviour of fish, amphibia and reptiles can be derived from an aquarium or vivarium. If a colony of locusts is kept, copulation may often be seen. Once animals came on to land, the sperm and egg had to be protected and internal fertilisation and adequate protection of the young developed.

Opportunity should be taken to discuss the "efficiency" of the different methods of reproduction. Brief comparison could be made between birds and mammals, including the relative size of the egg cell in each animal group.

A simple account of the oestrus cycle and the fact of egg cells not being released continuously should lead to an understanding of the mechanism of fertilisation in man.

John Merrigan's book "The Sixth Day", which is referred to at the beginning of this memorandum, gives interesting background reading, and the Teacher's Edition at £1.50 is recommended.

The BBC booklets for School Broadcasts provide excellent illustrations for the making of suitable charts or other records.

Section 6.4 The growing embryo

The need for the growing embryo for food, oxygen and protection is well illustrated by the development of fertilised chick eggs. These can be obtained from a supplier and kept at constant temperature in an incubator (advice on suitable models may be obtained from SSSERC). The temperature should be 38°C throughout, and adequate ventilation and humidity should be maintained. Each egg should be marked with an X and O at opposite sides and turned daily to prevent the membranes from sticking to the embryo. They may be left unturned over weekends. Warning! Care should be taken, when pupils take the eggs preparatory to opening them, to ensure that they are not turned on different sides after distribution. The opening of the 3½ day stage is very dramatic, as the heart can be seen beating and the embryo, with its blood vessels spread over the yolk, making a beautiful and dynamic sight which impresses the pupils. (The diagram Figure 6.2 on page 89 of "Biology by Inquiry" Book 1 illustrates how to open an egg.) Later stages can be killed before opening by placing the eggs in a refrigerator for half-an-hour. As from the sixth day the embryo is obviously a bird and pupils may become upset. No eggs should be opened after the tenth day, either with the embryo alive or dead, and "museum" specimens, film or a series of still photographs should be used to show later development.

Provision of eggs and the number used are obviously related but it is suggested that a part of this work should be demonstration, or "stations", to avoid an excessive number of eggs. Whenever possible it is a good idea to allow a few eggs to complete incubation and hatch.

Dissection of a pregnant mammal is an obvious illustration, and opportunity should be taken to demonstrate the complexity of structure within its body. A collection of embryos should be gradually built up and comparison made between the bird and mammalian stages of development.

Pupils frequently ask the length of embryonic development, ie gestation periods, in different animals. A few examples are listed here:

Mouse	20 days
Rat	22 days
Rabbit	32 days
Cat, Dog, Guinea Pig	9 weeks
Pig	17 weeks
Sheep	21 weeks
Macaque Monkey	24 weeks
Cow	40 weeks
Horse	48 weeks
Rhinoceros	78 weeks
Elephant	87 weeks - (20 months)

There is good film material on the birth of mammals, including Man, and any account of birth should include a description of the care of the young - elephants and Man having the longest childhood!

The development and structure of the fruit can be illustrated from a number of sources. A cucumber is a good example of fruit structure which clearly shows the food ducts to the seeds. Formal classification of dispersal is quite unnecessary but there is scope for interesting field observations on the dispersal of young plants from the parent and the spread of a plant population eg Fireweed or the Rosebay Willow Herb; the distribution of young sycamore trees; sweet vernal grass, of which the "awned" seeds burrow into the soil.

An interesting comparison could be derived between germinating seeds and the developing hens' eggs. The necessity for a basic food store is essential to subsequent development.

IV References

R A Clarke et al "Biology by Inquiry" Book 1 Heinemann

J Merrigan "The Sixth Day" Darton, Longman and Todd

Nuffield Biology Text Guide and Text Book 1 Longmans-Penguin

SSSERC Scottish Schools Science Equipment Research Centre
103 Broughton Street
Edinburgh
EH13 RZ

SECTIONS 7 AND 15
ELECTRICITY AND MAGNETISM

I Introduction

These two sections form a unit and are therefore considered together here. They are separated in the syllabus; otherwise too large a section would result. As the syllabus points out, no future citizen or householder can afford to lack an elementary knowledge of electricity. Our modern civilization is dependent on this means of securing and distributing energy. A few simple ideas can provide the layman with an intelligent interest in electricity as it operates in his/her home and also lay the basis for future hobbies or careers. These sections also offer many possibilities for realising the objectives of the course-compilers, quite apart from the teaching of the content. Simple electrical experiments provide unique opportunities for learning about techniques of experimentation, since the variables are easy to control and the observations easy to make.

Too often the topic of Electricity has been reserved for the later stages of school Science. Even with the early drafts of the alternative physics scheme many schools did not include it in the first two years work. For this reason the Working Party has included a section in the first year on basic circuitry and a later section in Year II on further applications, including electromagnetism. This means that each section is not over-long, an important consideration for syllabus constructors when dealing with young pupils, who demand variety if their attention is to be held. As positioned in the published course the first electricity section would be taught late in the first year, and trials have indicated that this position is suitable. However there is advantage to be gained in experimenting from year to year with the order and style of teaching a topic. It will be seen that no attempt has been made in graft chemistry and biology on to either electricity section. Cell chemistry is a difficult and unexciting introduction to the subject. It has also been recognised that an integrated course does not mean that every section must be forced into an integrated format - other sections lend themselves more naturally to this treatment.

In planning a lesson, a section of a syllabus, or indeed a complete syllabus, it is helpful to think of the educational process in cyclic form.

The first part of this process involves catching the attention of the pupils in some dramatic and exciting way (surely not difficult for us in Science) so that there is "the sudden perception of half-disclosed and half-hidden possibilities".* Examples of this will be found in the introduction to this course itself in the opening "romp" section and in the opening of the first electricity section. These are calculated to engender sufficient interest to build up the momentum necessary to take the pupils through the next, more difficult, stage. This second stage involves the hard work of taking the subject apart and beginning to understand it. This is where pupils should be exposed to some of the vocabulary, grammar and methods of Science. But this stage would be barren without the previous introductory phase, just as a third stage is required to round off the second. For knowledge gained at the second stage should not be kept in cold storage. (Knowledge does not keep any better than fish!) The third phase therefore involves not only the synthesis of the ideas but also experiences of the power of using them. Examples of this are seen in the closing parts of section 7, where the pupils apply their newly-gained ideas to the home situation, and in section 15, which closes by applying knowledge previously gained.

II Specific Objectives Pupils should acquire, in section 7,

1. the knowledge that there are only two types of electric charge called positive and negative
2. the knowledge that current is a flow of electrons
3. knowledge of certain basic facts about current, voltage and resistance in simple d c circuits
4. ability to apply the above knowledge in new problem situations
5. ability to work with multiple variables in these experiments
6. ability to generalise from particular observations in simple electrical circuits
7. ability to form a theory relating current to voltage, using observed phenomena
8. awareness of danger in using mains electricity
9. skills in simple wiring techniques

and in section 15

1. some information about the relationship between electrical units
2. some information about costing electrical energy
3. knowledge of the use of beam deflection in a C.R.T.
4. knowledge of some facts about discharge tubes

* A N Whitehead

5. knowledge of some facts about electromagnetism
6. knowledge of some facts about the motor effect and its applications
7. the knowledge that a current can be generated by relative motion of a closed coil and a magnetic field
8. the knowledge that there is a.c. as well as d.c.
9. ability to apply knowledge of electrical circuitry to domestic wiring
10. ability to analyse current relationships in parallel circuits
11. ability to calculate fuse values for given situations
12. awareness of the important technological revolutions resulting from the development of electromagnetics and the later development of electronics
13. awareness of and an interest in leisure pursuits in electronics
14. further skill in wiring techniques

III Experimental Details

a. Background

The first trials of this course produced many critical comments from schools, unaccustomed to teaching electricity as early as first year to this range of pupils. This feedback referred to loss of interest, particularly by the girls. Apparently the draft of section 7 was too long, introduced too many difficult ideas and did not maintain enthusiasm. At this stage the section was re-written around the circuit board as apparatus. Subsequent feedback confirmed that the main problems had been the time-consuming techniques of circuit assembly previously used and also the lack of relation of theoretical and practical layout. The circuit board solved these and allowed pupils of a wide range of ability, girls and boys, to obtain results sufficiently quickly to produce confidence, interest and understanding. The objective tests administered since then in comprehensive schools have produced data which confirm this success. (See Curriculum Paper No 7, paragraphs 51-53, and the Objective Test Memorandum for Year 1, items 66-79.)

b. Circuit Boards

At first sight the circuit board may seem to discourage open work for pupils of "divergent" tendencies. But there is much flexibility within the framework provided for the pupil, and the multiplicity of possible connections encourages further experiment. This type of provision has been called "stage-managed heurism", as a modification of the early heuristic ideal of allowing the pupils to dictate the syllabus. It is essential however to design such kits with as little pre-fabrication as possible to allow for this flexibility.

The Scottish Schools Science Equipment Research Centre bulletin No 5 of May 1966 gives a design for "Worcester" circuit boards, based on the dimension of the U2 cell. The alternative of using a low voltage supply does not offer the pupil a visual "unit" of voltage supply, to be added in experiments. Using cells, the voltmeter becomes a "cell-counter", and its function is easily differentiated from that of an ammeter by this means. It is advisable to match the bulbs used in a set. They could be coded with paint for example. It should be noted that some bulbs suffer a reduction in efficiency if overrun individually.

Introducing the circuit board requires careful thought. On the one hand we do not wish to inhibit the pupils' desire to experiment, on the other we do not want all our components to be ruined or lost within a few weeks. Firstly the pupils should be made responsibile for checking the items in the kit. (Even so, further checks should be made by the technician or assistant.) Then a warning against short-circuiting the cell is necessary. It will be noted that the experiment to demonstrate steel wire "fusing" has been labelled as a demonstration for this reason. In order to keep the kits operational a sufficient stock of spare parts is essential.

c. Electromagnetic and Electrostatic Kits

The "Westminster" electromagnetic kit is referred to in section 15 electricity. Again this provides the pupils with a suitable framework within which to conduct all kinds of experiments and to build meters and motors. This time it is important to use the special low voltage, high current, power supplies designed for use with this kit, since these allow the pupils freedom to experiment with the high currents required without blowing fuses or ruining cells. In both sections 7 and 15 the "Malvern" electrostatics kit is also useful in providing pupil apparatus made of modern materials. The electroscope is reserved for the second year, in order to supply a fresh approach at that stage.

d. Apporotus Demonds

In order to reduce the demand for apparatus in a school timetabled for setting all or a half of the first year pupils at Science at once, it is useful to change the order of the sections for some classes, say after section 4. Some could then follow the order 4-7, 5, 6 and others 4-5, 6, 7. In this way the demand for circuit boards, for example, is reduced. At the end of the first year all pupils will still have covered the same ground.

IV Units

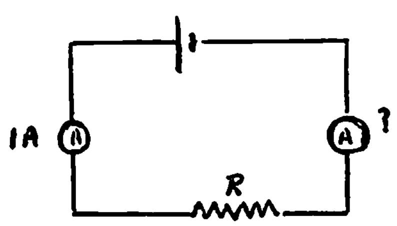
A summary sheet on some of the derived SI units used in the syllabus has been included in section 15 worksheets. Pupils brought up on this system have the possibility of forming a much clearer picture of the relationship between units than we probably had at school. It is suggested that the new units should be "anchored" to their experience in some way, eg a newton (N) is the weight of a medium sized apple. The joule (J) and watt (W) then follow easily.

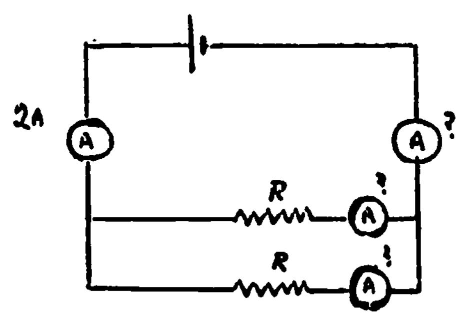
FORCE	N	
ENERGY	J	J = Nm
POWER	W	W = J/s

Examples of this application in everyday life should be pointed out. A domestic central heating boiler has an output of approximately 15 kW (not Btu/h) and a mini-car 25 kW (not hp). The 1 kW one-bar electric fire is a useful basis for comparison.

V Homework

It must be emphasised that the pupils should be warned against experimenting with mains voltage apparatus, unsupervised, at home. Homework is probably best confined to completing hand-outs of circuit diagrams such as:





The circuit board also lends itself to practical tests, when fault-finding exercises can be devised. Plastic-covered wires can be broken inside the sleeving, and blown bulbs or faulty switches provided. The solution of these problem-situations requires a logical procedure as well as the application of the ideas acquired in the section.

VI Visual Aids

For the teacher, there are the Esso-Nuffield firms:-

"The Worcester Circuit Board" and "The Electromagnetic Kit"

For pupils, any film which gives a simple mental picture of electron flow in wires is worth showing.

eg EDA - What is Electricity?
Rank - What is Electric Current?

VII References

Apart from the Worksheets already issued, much help will be found in the Nuffield Guides to Experiments, published by Longmans/Penguin.

Circuit Boards	:	Guide to Experiments II, Experiments 12-23
Electromagnetic kit	:	Guide to Experiments III, Experiments 80-88
Electrostatics kit	:	Guide to Experiments II, Experiments 35-38.

Many of the experiments suggested in sections 7 and 15 have been culled from these Guides to Experiments - as fair exchange for those adopted by the Nuffield Foundation from the Scottish alternative physics scheme. Many additional experiments are also suggested in these guides, useful with faster groups. Those on the current balance, for example, have not been included in this course since they constitute a more academic approach at this stage.

The Longmans Physics Topics. Series of background readers includes:

Electric Circuits, by Lewis and Heafford.

For Homework see:

Questions in Physics, Chapters 3 and 7, Houston, Heinemann.

Nuffield Physics Questions Book II sections 2-3
III sections 27-30, Longmans/Penguin.

SECTION 8 - SOME COMMON GASES

I Introduction

In this section we look at the ocean of air in which we live and consider its importance for ourselves and all other living things. The composition of air and its role in combustion are studied in some detail. A beginning is made with the investigation of photosynthesis but it should be remembered that this is only a first look at this very important process. Much more chemistry and biology must be studied before a full understanding is possible. The opportunity is taken at the same time to provide a little information about respiration and breathing. The section is to a large extent informative in nature, ten of the fifteen objectives being concemed with knowledge. It is the more important therefore to ensure that, where possible, opportunity should be taken to reinforce the more complex processes of thinking. The bulk of the work is concerned with air, a plentiful commodity which costs nothing, and on the occasions where design of experiment can be attempted, ample time should be allocated for the purpose.

II Specific Objectives Pupils should acquire

1. knowledge of identification tests for oxygen, nitrogen and carbon dioxide
2. knowledge of some basic facts about photosynthesis
3. the knowledge that carbon dioxide increases in exhaled breath after exercise
4. knowledge of facts about the carbon dioxide/oxygen balance in plants and animals
5. knowledge of the need for oxygen in combustion
6. knowledge of the approximate composition of air
7. some information about the noble gases
8. some information about the industrial processes for isolating oxygen andnitrogen
9. knowledge of some facts about respiration
10. ability to apply the above knowledge in new and problem situations
11. ability to draw conclusions from a mass of data (Section 8.1)
12. awareness of the need for a control experiment in assessing results of many experiments
13. awareness of the importance of plant/animal inter-relationship in the world
14. awareness of the industrial importance of the gases of the air
15. some simple techniques in biology and chemistry, eg use of microscope, use of indicator, etc.

III Experimental Details

Section 8.1 Oxygen, nitrogen, and carbon dioxide

Sheet 1 The Identity Pardade

The existence of air may have to be discovered and means of "seeing" an invisible gas devised. The kinetic model for gases is referred to again and the difficulty of collecting a gas discussed. The problem of the different densitiesof the gases is also discussed. Methods of collecting the gases are now considered. It is found that collecting gases over water lets the pupil see a test tube actually filling with the gas to be tested - no problem arises if the gas is not particularly soluble in water.

The gases are supplied from cylinders and no reference is made as to how the gas is made - it has simply been bought! Since pupils should not tamper with gas cylinders, the teacher or laboratory technician should control the cylinder, but does the rest. To save time he may collect several test tubes of the gas over water and close the tubes with a stopper. Other methods of supplying the gases should be tried to speed up the operation, eg supplying polythene bags full of gas to the pupil, who will then collect test tubes of the gas from the bag in the usual way. Altematively, aspirators full of the gas may be set up for the use of the pupils.

One gas at a time should be studied. The pupil should discover its solubility in tap water, its effect on a burning taper and a glowing splint, its effect on moist pH paper, and its effect on lime water or bicarbonate indicator. This causes less confusion than studying one property for all three gases each time. The results are tabulated, examined and conclusions drawn. The pupils should be able to identify each of the gases and should know the general properties of each. It is important that pupils realise that *one* property alone may not identify the gas, eg if the gas extinquishes a burning taper, does this mean the gas is nitrogen?

The teacher now demonstrates the burning of magnesium in each of the gases and the results are added to the pupils' tables. This raises many problems which can be examined later in Section 8.4, eg what is the white powder formed when magnesium burns in oxygen? What is the white powder and black specks formed when magnesium burns in carbon dioxide?

Collecting gases for testing

The gases should be collected over water in 150 mm x 25 mm test tubes.

The gas may be supplied directly from a cylinder (controlled by teacher) or, preferably, by supplying pupils with:-

a. Polythene bags full of the gas and the name of the gas printed clearly on them.

   Bags approximately 25 cm x 15 cm will be big enough to supply about 8 test tubes full. The mouth of the bag is secured tightly round a rubber stopper by an elastic band. A groove is cut in the stopper to take the band. The stopper carries a glass tube to which is connected a rubber tube and clip. See Nuffield Chemistry. The Sample Scheme, Stage I Topic B.4.

or b. Aspirators full of the gas and clearly labelled are supplied to groups of the pupils.

In both a. and b. the pupils can now easily and quickly fill their test tubes for the test. It is as well to fit stoppers on to the test tubes to prevent the gases escaping.

A 150 mm x 25 mm test tube is suitable for pupils' tests, but a wider gas jar should be used for the demonstration of burning magnesium.

The solubility tests are done by inverting the test tube into fresh tap water in a beaker. This is left for some time and the test tube is slowly raised to see if the water has entered. Discuss beforehand.

eg What would happen to the water level if some gas is removed, eg by dissolving? This can be demonstrated by sucking some of the air out through a rubber tube. After discovering that tap water already contains dissolved air, pupils may want to repeat this experiment with air-free water.

Time:- About 5 periods.

Section 8.2 Energy and Photosynthesis

Common foods are traced back to plants:

mutton $\longrightarrow$ sheep $\longrightarrow$ grass

Simple food webs should be drawn up:

producers (green plants) $\longrightarrow$ primary consumers (herbivores) $\longrightarrow$ secondary consumers (carnivores)

Photosynthesis should be dealt with simply, showing the removal of carbon dioxide from air around a green plant, the formation of starch in green parts of leaves, and building of starch from sugar. The study of a leaf should also be simple, showing stomata, airspaces and chlorophyll in chloroplasts. No mention of epidermis, veins and mesophyll is wanted.

The evolution of oxygen from a water plant should be shown and the importance of photosynthesis strongly emphasised.

The following techniques should be learnt in this sub-section:-

Use of a microscope.
Use of a control experiment.
Collection of small quantities of gas for identification.

Pupils should help to design experiments to collect and test the gas from pondweed and solve the problems involved in this.

The following hypothesis should be put forward:-

Carbon dioxide is removed from the air around leaves when they are illuminated and used to build sugars and then starch in leaves.

This can be tested by pupils bringing in other leaves to test.

The following information should be accumulated.

1. Chlorophyll is necessary for starch production.
2. Light energy is necessary for starch production.
3. Plants produce oxygen.
4. Energy in food comes from the sun.

Plants and carbon dioxide

A bicarbonate indicator is obtainable from BDH. Information regarding its composition is in Nuffield Biology Teachers' Guide pages 7 and 8.

To aspirate the indicator, air from outside the laboratory should be used, and the colour should eventually appear deep red. See Nuffield Biology Text III pages 120-121

If not already done, the colour changes should be shown with one drop vinegar or lemon juice and one drop dilute sodium hydroxide.

$$\text{yellow} \xrightarrow[\text{more acid}]{} \text{orange} \qquad \text{red} \xrightarrow[\text{more alkaline}]{} \text{purple}$$

In 8.1 the pupils will have seen the effect of increased carbon dioxide content on the indicator. They must now see the effect of lack of carbon dioxide before they can deduce that it is removed in photosynthesis - hence the need for a tube containing indicator and soda-lime.

Care is necessary when using the bicarbonate indicator. Do not breathe on it and do not touch the inside of the apparatus with the fingers as these will both affect the indicator. Rinse all the apparatus with distilled water and use tweezers to place things in the apparatus.

The lamp of a projector can be used to illuminate the leaves and plants. The heat produced by the bulb can be ignored unless a pupil questions this. A water bath can be used to stabilize the temperature. See Nuffield Biology Text III pages 114-115.

Photosynthesis (3 sheets)

Bunsens should be extinguished to avoid setting the alcohol (ethanol) alight.

Geranium leaves (and begonia semper florens) are suitable for starch tests, since both grow quite happily in the laboratory. If neither of these are available, try others but avoid thick, glossy ones.

If yellow iodine traces spoil the results, wash in benzene. [Care: dangerous vapour.]

N.B. Take care with potassium hydroxide; do not allow pupils to handle it.

Vaseline is smeared on the rim of the bell jar, which is then put over the plant which stands on glass or formica. Press the bell jar firmly.

For a variegated leaf, wandering sailor (tradescantion) or privet are suitable. Check that drawing has been made with zones carefully marked. See Nuffield Biology Teachers' Guide page 157.

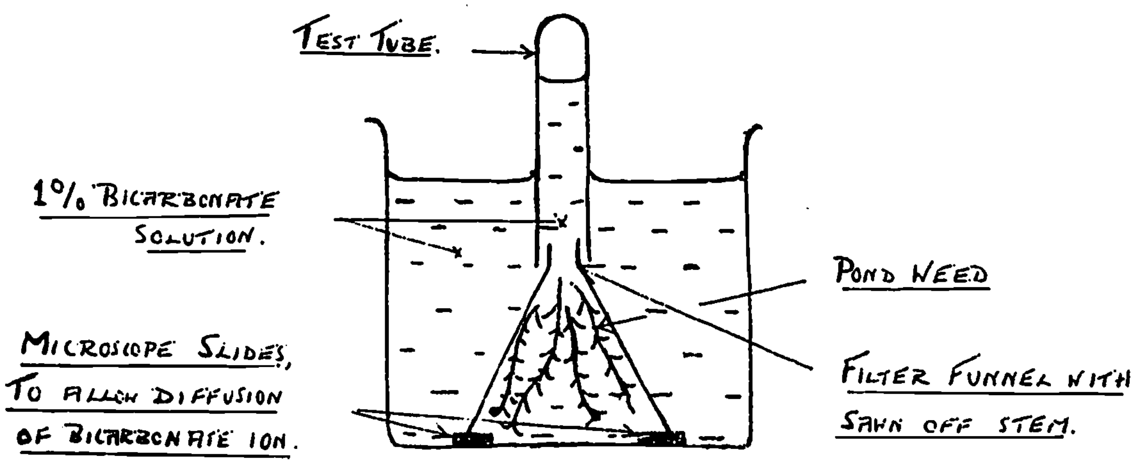
To show that starch can be built from glucose, leaf discs (from geranium etc, which has been in the dark for two days) are floated in 5 per cent glucose solution in dark for three days, then tested for starch as before. See Nuffield Biology Text III page 135.

It is possible to show sugar in Iris leaves but this is rather difficult for the majority of pupils. See Nuffield Biology Text III pages 140-143.

Having shown "no chlorophyll, no starch", chlorophyll can be seen by examining pondweed under the microscope.

Pupils can examine leaf structure from a photomicrograph in a viewer.

To show evolution of oxygen from a water plant, set up several sets of the apparatus shown below and illuminate with a bench lamp. Pupils can suggest tests to identify the gas, and one test can be done on each sample.



Alternatively, a gas burette, with suba-seal bung, may be used in place of the test tube; in this case the gas sample may be withdrawn through the cap by a syringe fitted with needle.

Discussion at the end of this section should bring out that plants are producers of foods and animals are consumers.

Time:- About 8 periods.

Section 8.3 Unbreathed and breathed air

No attempt should be made to calculate the increase in proportion of carbon dioxide or decrease in proportion of oxygen.

Pupils should be able to design an apparatus to collect exhaled air if they have already seen the method of collecting a gas in 8.1. They should also be able to design an experiment to show the removal of oxygen from air by a small invertebrate. (This could be set as homework and any reasonable experiment tried.)

The following hypotheses should be formed:-

Oxygen is exchanged for carbon dioxide inside our bodies. Foods have energy locked up in them.

The pupils should know that

1. Air breathed out contained more carbon dioxide, less oxygen, is warmer and contains more moisture than air breathed in.
2. Food burns to give carbon dioxide and water.

Unbreathed and breathed air

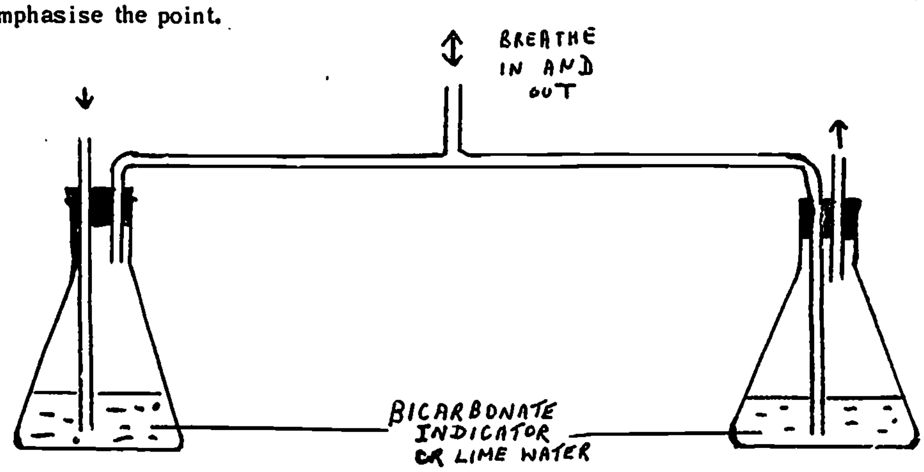
(1st sheet)

Do not allow pupils to breathe the same air in and out more than five times. Reports have been heard of pupils collapsing where breathing the same air in and out too often.

Pupils should try to design a method for collection of gas. See Nuffield Biology Text III page 2.

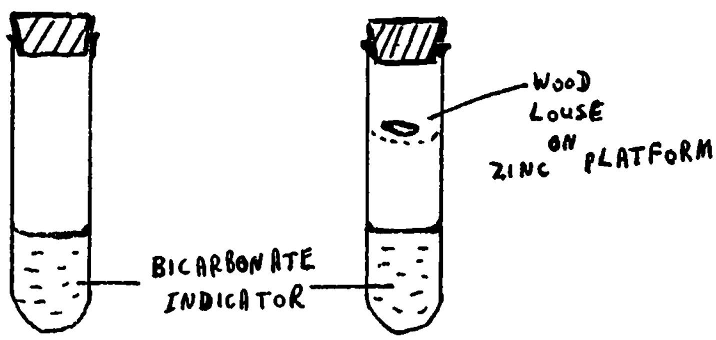
Pupils should realise that breathed and unbreathed air both contain oxygen and carbon dioxide. It is the quantity that varies.

To compare the quantity of carbon dioxide in both inhaled and exhaled air, the following experiment might be done to emphasise the point.



An additional demonstration could be inserted here to show that other living things produce carbon dioxide.

The apparatus shown below is set up. The wood-louse tube will soon change colour.



An alternative technique for comparing inhaled and exhaled air is described in SSSERC Bulletin 36.

Unbreathed and breathed air

(2nd sheet)

Removal of Oxygen by living things: Marker bubble moves towards test tube showing removal of a gas from the air.

Burning food-stuffs: Perfectly straight-forward. Pupils can provide foodstuffs. Groups can do different ones and compare. Less able pupils will require some encouragement to obtain answers to questions 3 and 4.

Time:- About 4 periods.

Section 8.4 Composition of Air (2 sheets)

It is worth emphasising at this stage that burning will cease when all the material has been changed even though we have a supply of air, that burning will only take place when the temperature of the combustible material has been raised sufficiently, and that energy is liberated during burning. An interesting demonstration at this stage is to let air into a light bulb and show how quickly it burns out when switched on.

The next question arises naturally. Is all the air used up when a substance burns? Float a candle in water. As the candle burns the water rises part of the way up inside the jar. What conclusions can be drawn? This experiment raises more problems than it solves, but it is useful for teaching scientific method. What is the nature of the gas left? Test. It does not support combustion and is rich in carbon dioxide. Was this left over from the air after burning took place or was it formed during burning? What is the mist formed on the inside of the jar during burning?

There is no need to carry out the traditional experiments to determine the volumetric composition of the air. Instead it is suggested that various mixtures of nitrogen and oxygen should be prepared and tested with burning splints. The mixture which provides combustion most like that of normal air will give a reasonable estimate of the composition. The presence of the noble gases is mentioned and may be introduced by referring to the work of Ramsay. An interesting extra would be to relate the story of the discovery of helium on the sun before it was discovered on earth and show the characteristic colours of helium, argon and neon discharge tubes and view them with the spectroscope.

By reference to the properties of the gases of the air their uses are discussed. The properties of liquid air and solid carbon dioxide should be demonstrated simply, if possible, but great care should be used in handling these substances.

It is possible to discuss the preparation of oxygen and nitrogen from air by fractional distillation of liquid air.

It is also useful to discuss a typical analysis of an air sample, since the pupils have only arrived at a very rough analysis and we have created such problems as:- What volume of the air is made up of noble gases?

eg	Dry Air	By Volume
	Nitrogen	78.03%
	Oxygen	20.99%
	Noble Gases	0.95%
	Carbon Dioxide	0.03%

There are fairly constant from place to place. Water vapour varies. The average is about 1 per cent by volume but may reach 4 per cent in humid climates.

Time:- About 5 periods.

This can also be done with a little magnesium powder in a pyrex test tube. In one case the test tube is full of air and in the other case the air is extracted with a good pump. The magnesium does not burn in the second case, although a little reaction with the glass takes place.

The heating of magnesium in a vacuum inside a bell jar can also be demonstrated. Here the powder is heated by passing an electric current through a coil of nichrome wire dipped into a deflagrating spoon containing the powder. A good pump is essential and a small bell jar (1-1½ litre capacity) is the most suitable.

To produce a cold surface to show water vapour in the air, rapidly evaporating ether in a test tube with side arm connected to a pump may be used. The water can be collected and identified. However, pupils may get satisfactory results from a freezing mixture of ice and salt in a test tube or by the teacher squirting a little Aerosol Freezer into a test tube for them. This is supplied by Radiospares.

Time:- About 5 periods

Section 8.5 Solubility of air in water

Discussion should bring out the importance to life of the oxygen dissolved in water.

A large flask is necessary if a reasonable quantity of air is to be obtained.

Time:- 1 period.

Section 8.6 Release of energy: respiration

This should bring out the information that living things release energy. After comparison with burning food and discussion, the following hypothesis should be formed:-

> Food is "burned" slowly inside our bodies to form water and carbon dioxide and energy is released. This energy is used for heat, movement, etc.

Bodies of living things use their food as fuel to keep them alive.

Time:- 1 period.

Revision of energy released from food is important. An experiment to show that a living organism produces heat could be germinated peas in a vacuum flask. The peas must be soaked in water until the radicle has emerged (about three days). Half the peas are then killed by boiling and put in one flask, and the living half are put in another. Cover with formalin to prevent bacterial action. Observe temperature changes.

Nuffield suggests another experiment. See Biology Text III page 35.

Time:- 1 period.

Section 8.7 Respirotory system

This should give some understanding of how breathing takes place and an idea of the structure of the respiratory system. The technique of use of models to demonstrate particular functions is introduced here.

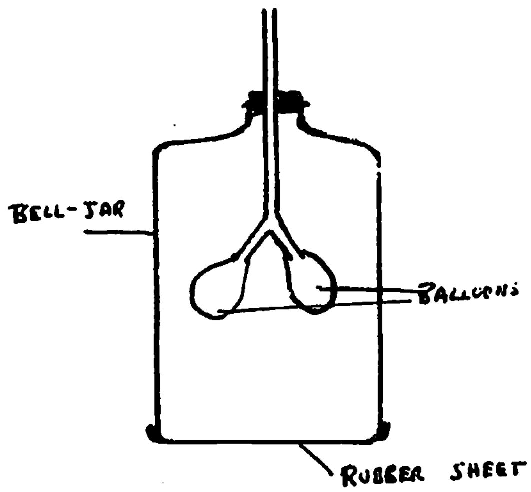
Hypotheses can be formed as to how breathing takes place.

Pupils should realise the extent of the lungs. (Many imagine these as being very small.)

They should have some idea of the diaphragm, and also of the trachea bronchi and airsac from the examination of a sheep's lungs. (A sheep is roughly the same size as a human.)

Examine sheep's lungs showing windpipe with rings splitting into two bronchi; one going to each lung. Show bronchial tubes branching and becoming smaller each time. Explain these end-in-air sacs where the diffusion of gases takes place. Give a diagram showing these.

A model should be set up to show the action of the diaphragm. The rubber sheet should be fixed firmly round the bell jar. As it is pulled down the balloons inflate.



Another model should be shown to demonstrate the action of intercostal muscles. See Nuffield Biology Text III page 17.

Film loops can be obtained to show the mechanism of breathing and to demonstrate artificial respiration. Some discussion should establish when artificial respiration might be necessary.

IV Some Suggested Examples for Homework

What is an iron lung used for?
Bring in fish heads and examine the gills.
How does a water beetle breathe? Observe in the laboratory and find out.
Why do athletes, tennis players etc eat glucose just before or during a match?
Design apparatus to collect the gas in lemonade for testing.
Write an account of where energy in coal came from.
List as many pieces of evidence as you have observed which show that air exists.
Using an "empty" 1 lb jam jar and a bucket of water, and anything else you need, find as much evidence as possible which shows that the jar is full of air.
How would you find the exact position of a puncture in the inner tube of a bicycle tyre?
Find out from the library the height to which the atmosphere rises.

Three stoppered bottles are unlabelled but one is known to contain oxygen, one nitrogen and one carbon dioxide. How would you find out which is which? Enter your results in the table:-

BOTTLE	IDENTIFYING TESTS	NAME OF GAS
A		
B		
C		

List as many everyday processes as you have observed which require oxygen and which illustrate that oxygen is an essential part of the atmosphere.

What purpose does carbon dioxide serve?
What is an oxygen tent used for?
Make a list of uses to which man puts (a) oxygen, (b) nitrogen, and (c) carbon dioxide.
Find out from a chemistry book the gases found in the atmosphere and the percentage of each.
What is the effect on a fire if:-

a. oxygen is kept away from it
b. it is cooled below the ignition temperature of the burning material
c. the unburnt material is removed.

State how a. and b. may be accomplished in fighting actual fires.
Find out as much as you can from the library about the work done by Lavoisier and Priestley.
Write a short summary of the importance of air.
What gas is used by divers working in deep water? Why?
Find out the uses to which the noble gases are put.
What is the gas in a "gas filled" electric bulb.

V References

Teaching of Biology. Jean B Bremner Macmillian
Animal Ecology: Aims and Methods. A McFadyen (1963) 2nd edition Pitman
Royal College of Physician of London (1962) Smoking and Health Pitman
The iron lung. F W Jones, Science Master's Book, Series III, Part III, pages 198-199 Murray
Chemistry takes Shape and Teachers' Guide Book 1, Johnstone and Morrison Heinemann
A Modern Approach to Chemistry Stove and Phillips Heinemann
The Elements of the Universe Seaborg and Valens Methuen
SED Memorandum No 3, Alternative Chemistry
Nuffield Chemistry Stage 1 Topics A3, A4, B4, B9
Nuffield Chemistry Collected Experiments E1.6, E1.7, E2.6, E2.16, E3.1 to E3.12
Nuffield Laboratory Investigations Stage 1A and 1B
Nuffield Laboratory Investigations Stage 1A and 1B
Nuffield Background Books (Paperbacks) eg Burning and The Discovery of the Inert Gases

Unesco Source Book for Science Teaching Chapter VII, A, B, J, K.
Chapter VIII C and D. Educational Productions Limited
Lecture Experiments in Chemistry 6th Edition G Fowles Bell & Sons Ltd
School Science Review, November 1965, Chemistry IV Air and Fire

VI Visual Aids

Film loops:-

Breathing and artificial respiration	BA/013
Structure of green plant	BB/281
(advanced but useful for leaf structure, showing chloroplasts etc)	
Chlorophyll extraction	NCP 1-2

All from:- Ealing Scientific Limited
23 Leman Street
LONDON E1

Photomicrographs:- These can be projected on to a screen or used in viewers for the purpose of making drawings.

Lung HP Bronchiole	N156
TS Trachea	H45
Mammalian Lung	H44
Iris and surface view of stomata	B58
Ilex TS Lamina	B59

All from:- South West Optical Instruments Ltd
Hooper's Pool
Southwick
Trowbridge
Wiltshire

Bioviewers:- Banta (Education Suppliers)
60 Hopton Road
London SW 16

These show film strips, are not very expensive and are meant for individual use.

How living lings breathe	No 21
Photosynthesis	No 59
Respiratory System	No 72
Smoking and Health	No 73

16 mm Films:- The following films, although not of value as a direct teaching aid for this section, contain useful material (although somewhat advanced in places). They may therefore be shown as an "extra" if time permits, or as part of the Science club programme at the time this section is being taught.

Fire Chemistry, Scottish Central Film Library
Fire - What makes it burn. Scottish Central Film Library

The History and Discovery of Oxygen. ICI

"O" for Oxygen. British Oxygen Company

Charts:- Educational Productions Limited

C573	Oxygen Production
C707	Uses of Oxygen
C902	Uses for Nitrogen
C896	Uses of the Inert Gases.

WORKING PARTY ON SECONDARY SCIENCE

INTEGRATED SCIENCE COURSE

Memoranda for Teachers
Sections 9-14 (Year II)

Scottish Education Department

SED Working Party on Secondary Science

INTEGRATED SCIENCE COURSE

Memoranda for Teachers: Sections 9-14 (Year II)

This set of memoranda offers guidance on the teaching of each section of the Integrated Science Course in some detail. The memoranda have been written mainly by practising teachers, experienced in teaching the syllabus at the pilot stages. It is hoped that their advice can help colleagues find their way through the course more easily and effectively.

The materials now available from the Working Party are:

1. Curriculum Paper No. 7 "Science for General Education", published by HMSO, including:
    a. Content of the Integrated Science Course suggested for the first cycle, Years I and II.
    b. Specific Objectives for each of the 15 sections.
    c. Specimen science topics for the second cycle.

2. Apparatus lists for Years I and II, which have been distributed directly to all secondary schools by SSSERC, the National Science Equipment Centre.

Ancillary Materials which have been distributed to all secondary schools by HMSO via Education Authority offices

3. Worksheets for pupil use in Years I and II.
4. Objective Test Items for Year I (Year II to follow).
5. Science Topics for Years III and IV non-SCE Courses, 18 "Brunton" Topics (12 more to follow).
6. *Memoranda* for teachers, Sections 1-8 (Year I).
7. This present publication, *Memoranda* for Sections 9-14 (Year II).

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The teaching notes given here have been provided by many different people and the Working Party would like to express its gratitude to them for the help they have given. It is not possible to name all who have submitted material but major contributions have come from the following.

Mr J Henderson	Jordanhill College of Education Glasgow
Mr J McClune	St Aelreds Secondary School Paisley
Mrs Mutch	Balwearie Secondary School Kirkcaldy
Miss P Boyd	Boroughmuir Secondary School Edinburgh
Mr W Gauld	Boroughmuir Secondary School Edinburgh
Sister M Julie	Notre Dame High School Glasgow
Mr A W J Brooks	Science Adviser Fife Education Committee
Miss A Simpson	Paisley Grammar School

Members of the Working Party have also contributed along with HMII.
The Working Party is listed on page 2 of Curriculum Paper 7

GENERAL BACKGROUND THEORY ON EDUCATIONAL OBJECTIVES

1. J Bruner: The Process of Education, Harvard University
2. R Tyler: Basic Principles of Curriculum and Instruction, Chicago University
3. B Bloom: Taxonomy of Educational Objectives I + II, Longmans
4. R Mager: Preparing Instructional Objectives, ESL
5. J Houston: Principles of Objective Testing in Physics, Heinemann
6. W Hedges: Testing and Evaluation for the Sciences, Wadsworth, California.

SECTION 9 - MAKING HEAT FLOW

I Introduction

The Alternative Physics syllabus of 1962 incorporated a section on "Flow", including flow of fluids, electric charge and heat. The fluid flow part included an interesting digression on the Bernouilli effect. The 1969 Physics syllabus has dropped this section as part of the reduction in content found necessary to allow teachers to place more emphasis on the other dimension of a syllabus specification - the objectives of teaching (see Curriculum Paper 7 paragraph 44).

This present section on heat flow has always been included in elementary science courses, providing a good introduction to the topic of heat, some interesting experiments and much relevance to everyday life. The treatment suggested attempts to keep the time required to the minimum by providing a further unit of "stations" experiments. This is also an opportunity to apply the concept of energy in a section which may well form the introduction to a new session.

The 1969 Physics syllabus points out that the word "heat" strictly should be used for energy transferred by a temperature gradient and not confused with the internal energy of a body. In other words we should guard against talking about the heat *in* a body and confine the use of the term to energy leaving or entering a body. It is hoped that pupils will gradually adopt the correct usage by example.

II Specific Objectives Pupils should acquire

1. the knowledge that heat energy is transferred in three ways, by conduction, convection and radiation
2. further knowledge of the concept of energy
3. ability to apply this knowledge to new and problem situations
4. ability to analyse data and draw conclusions (factors affecting heat loss and gain by one of these processes)
5. ability to analyse complex situations to identify the elements (identifying individual methods of heat transfer within a complex)
6. awareness of the phenomena of conduction, convection and radiation, defined in operational terms
7. awareness of the importance of heat to mankind
8. awareness of the need for conservation of sources of heat energy
9. skill in the use of measuring instruments and simple apparatus

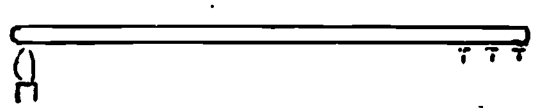
III Experimental Details

Section 9.1 Methods of heat transfer

Firstly the three methods of heat transfer should be demonstrated and discussed. This clears the way for later stations experiments. Some pupils should be able to offer simple explanations of conduction and convection in terms of moving particles.

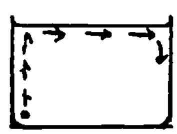
The use of a phototransistor wired to a micro-ammeter as a detector of radiant heat is introduced.

Conduction Rivets or drawing pins are attached with wax or vaseline along a copper rod and the rod heated at one end.

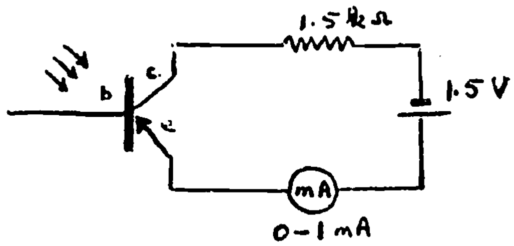


The rivet nearest the heat source falls off first, second nearest next etc.

Convection Cold water is put in a Pyrex beaker and placed on a tripod stand without gauze. *One* crystal of potassium permanganate is added and then a small bunsen flame is placed directly under the crystal.



Radiation To detect radiant heat a phototransistor (OCP71) is used. It is simple to use and very sensitive. (See Physics is Fun Book II page 3.)



Limitation of the senses as a detector can be mentioned here again.

Section 9.2 Problem Situations

A series of experiments as on the worksheets can be set up as a round of stations.

At the end of this section pupils should know the three methods of heat transfer and be able to apply this to problem situations.

They should also know:

a. Air, water, hair, feathers are poor conductors of heat.
b. Copper is a better conductor than brass or iron (many pupils after doing experiment 1 tend to think iron does not conduct heat).
c. Hot fluids rise.
d. Dull surfaces are bad reflectors and good absorbers of heat.
e. Polished surfaces are good reflectors of heat and bad absorbers.
f. Vacuum flasks keep hot things hot when the vacuum is intact.

Various hypotheses should be formed, eg

Heated fluids expand and rise.
Radiation can travel through a vacuum.
Vacuum flasks can keep cold things cold.

There are many alternative experiments to those on the worksheets. If time permits these could be tried or some of them done as homework. Able pupils should be able to suggest experiments to test their hypotheses.

IV Homework

There are countless possibilities for practical and written homework. The following are a few ideas; no doubt the teacher will be able to think of many more.

a. Find out kind of clothes worn on (i) a polar expedition (ii) a desert expedition.
b. Find the difference in time for day one pint of cold water to boil in a pot with a lid and one pint of cold water in a pot without a lid. List the things which will have to be kept constant.
c. Find out if a shiny teapot keeps tea warm for a longer time than a dull one.
d. How long will ice remain solid in a vacuum flask? [Warn pupils to take care in putting ice in the flask if it has a narrow neck.] Compare the time with the time tea will stay hot in the same flask.
e. Discuss or find out about insulation in 'fridges, ovens, lofts etc. Explain why the snow lies longer on a house with an insulated loft than on a similar house with an unlined loft.

V Visual aids

Film loops from - Ealing Scientific Limited,
23 Leman Street,
LONDON E1

SP/H/2 The emission and absorption of radiation.
SP/H/3 Reflection of radiation.
SP/H/4 The Convection of water.

Films 16 mm Scottish Central Film Library,
16-17 Woodside Terrace,
Glasgow C3.

D 2182 Heat - its nature and transfer.
DB6 Leslie's Cube.

Transference of heat series.

DCF 2664 Convection)
DCF 2665 Conduction) These are in colour and are free.
DCF 2666 Radiation)

See Esso-Nuffield teachers' film "Experiments in Heat Radiation", one of a series available free of charge from:

Travelling Films Limited
78 Victoria Road
Surbiton
Surrey

(see SED Science Newsletter No 6 page 24).

VI References

Physics is Fun and Teachers' Guide, volume II, chapter 3, Jardine, published by Heinemann.

SECTION 10 - HYDROGEN, ACID AND ALKALIS

I Introduction

In developing the work in this section, pupils will become familiar with some of the properties of hydrogen gas and will also establish the chemical composition of water. The section is essentially practical in its nature and lends itself well to the development of experimental techniques by the pupils, such as the simple "titration" procedure suggested for neutralisation reactions. The interest level is high, for most pupils enjoy working with hydrogen and the colour changes associated with indicators never fail to fascinate. The opportunity afforded pupils to design and carry out their own experiments is an important aspect of this course and the section provides this in full measure, without recourse to elaborate or difficult techniques. Many everyday substances can be involved in the work with acids and alkalis and this should provide valuable homework exercises of a practical nature. Similarly the class work on neutralisation and the reactivity of metals have obvious extensions into the world at large and could form the basis of simple "projects" involving investigations outwith the normal Science periods.

NOTE. Small samples only of hydrogen should be used and it should be possible to supply sufficient samples of the pure gas by the conventional methods of reacting a metal such as zinc with a dilute acid. The use of hydrogen in cylinders is not recommended.

II Specific Objectives Pupils should acquire

1. knowledge of a test for the identification of hydrogen
2. the knowledge that water is formed when hydrogen is burned
3. the knowledge that certain metals react with water at room temperature (sodium, calcium, magnesium)
4. the knowledge that certain metals displace hydrogen from dilute acid (magnesium, aluminium, iron, tin)
5. the knowledge that other metals do not displace hydrogen from dilute acid (lead, copper, silver, mercury)
6. the knowledge that there is a gradation of reactivity among the common metals
7. the knowledge that pH is a measure of the degree of acidity of a solution
8. the knowledge that acid and alkali are names given to solutions at opposite ends of the pH scale
9. the knowledge that acids neutralise alkalis
10. the knowledge that there is a simple quantitative relationship in neutralising acids with alkalis
11. awareness of the processes involved in identifying a chemical substance
12. awareness of the use of standard scales for comparison purposes
13. skills in handling simple chemicals and glassware
14. awareness of the dangers of handling hydrogen in large quantities.

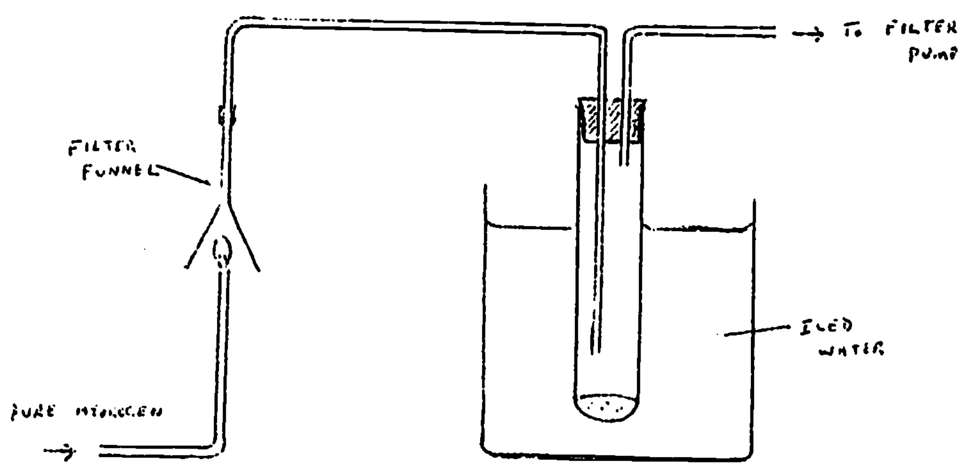
III Experimental Details

Section 10.1 Hydrogen

By the demonstration of the ignition of small samples of pure hydrogen and of hydrogen mixed with air, the explosive nature of the mixture can be established so that pupils will know that hydrogen burns and may do so explosively when mixed with air.

Section 10.2 The burning of hydrogen

The burning of hydrogen can be demonstrated using the apparatus shown.



The flame is placed beneath an inverted filter funnel or bent thistle funnel as shown. A filter pump is attached to "suck" the products of the combustion through a receiver which is cooled in a beaker of iced water. *This demonstration should only be undertaken by an experienced teacher who is aware of the potential dangers. A safety screen should be used.* Previous work will have established the fact that water freezes at 0°C and boils at 100°C. The anhydrous copper sulphate test for water does not indicate that a liquid is pure water. Furthermore it would be inappropriate at this stage as the idea of water of crystallisation has not been encountered.

In section 8 oxygen and nitrogen were mixed in various proportions to obtain a mixture which in its properties resembled air as closely as possible - no energy change was observed as a result of mixing these gases. The situation with hydrogen and oxygen is radically different. A chemical reaction producing an appreciable energy change is involved before the liquid water is obtained. Recalling that the burning of an element in air involves the formation of an oxide of the element, the class is now in a position to establish the important point that water is the compound hydrogen oxide.

The energy liberated when two volumes of hydrogen and one volume of oxygen combine may be demonstrated by exploding the mixture in a *small* lightweight polythene bottle (the capacity of the bottle must not exceed 200-250 ml). The explosion is very noisy and pupils should be advised of this before the experiment is performed. The explosion frequently results in the bottle becoming "jet-propelled". Pupils should be kept at a safe distance from it.

Useful teaching points can be made in establishing, with the class's help, a method of filling the polythene bottle so that it is one-third full of oxygen and two-thirds full of hydrogen. Will the order of filling the bottle with the two gases make any difference to the experiment?

Section 10.3 Action of metals on cold water

a. Calcium is a suitable metal to start this investigation. The gas produced can be collected in small test-tubes and, by application of the various tests available to them, can be identified as hydrogen. Frequently the calcium rises to the surface and this observation can lead to fruitful discussion. In a preliminary discussion the point can be made that calcium is an element (reference to periodic table), a concept with which the pupils are already familiar, so that the hydrogen can be deduced as coming from the compound water and not from the metal itself.

b. Magnesium. Using magnesium ribbon only a small quantity of gas is obtained after several days but there is normally sufficient to show that the gas is in fact hydrogen. As an additional experiment compare rate of evolution of gas using magnesium powder. Relate this to the surface area.

c. Sodium. The reaction between sodium and water is intended for demonstration by the teacher only and should be carried out with *small* pieces of sodium. *A suitable safety screen should be used.* The fact that the sodium is stored under a liquid such as naphtha will be immediately obvious to the pupils and will inevitably prompt the question - why? Discussion of this can be coupled with the tarnished appearance of sodium compared with the shiny appearance of a freshly exposed surface and lead to the conclusion that sodium and oxygen react very readily together. The rapid reaction of sodium and water can then be discussed. *No attempt should be made to collect the hydrogen produced in this reaction eg by using a sodium spoon.*

The work so far described, using metals and water, can be seen partly as an extension of the knowledge previously gained-that water is the compound hydrogen oxide-but can also be seen as an introduction to the concept of the varying reactivities of different metals in similar chemical reactions.

Section 10.4 Action of metals on dilute acids

The idea of a reactivity series is reinforced and extended to include a larger range of metals. Water is a compound containing hydrogen, displaceable by metals such as calcium and magnesium. Dilute hydrochloric acid acts as a much better source of hydrogen in this respect and the first experiment uses magnesium ribbon and dilute hydrochloric acid to convince the pupil of this fact. Other acids such as sulphuric acid, acetic acid etc should not be introduced in preliminary experiments as the main emphasis should be on the metals themselves. The metals silver and mercury should be demonstrated but the results can be included with the other results obtained by the class. From the combined results an order of reactivity can be arrived at by the pupils. Where possible the metals should be supplied as foil which has been fully cleansed; 5 M hydrochloric acid is appropriate. The acid should be used at room temperature only in these experiments; more observant pupils will however note that in the more vigorous reactions a rise of temperature is obtained

and this should provoke a valuable discussion. The metal samples used should be as far as possible of a similar size. The reason for doing this can be considered and some members of the class might experiment with the effect of using a metal such as iron in varying particle sizes. Consideration of the order of reactivity arrived at on the basis of these experiments can initiate a class discussion on such matters as the tarnishing of metals, the storage of reactive metals, the use of certain metals in jewellery, the occurrence of certain free metals in the natural state etc.

A further challenge

If magnesium displaces hydrogen much more readily from solution of dilute hydrochloric acid then it does from water, what will be the effect of using varying dilutions of acid? This question raises an opportunity for the design of experiments by pupils themselves.

Various questions arise. Is there any need to keep the total volume of solution the same? Is there any upper limit to the quantity of magnesium chosen? Is there any lower limit to this quantity? What is a suitable way of getting "identical" pieces of magnesium ribbon? Does the temperature at which the reaction occurs have to be considered? It is not suggested that an approach of this nature will be within the scope of all the members of a class, nor that the conclusions obtained should be interpretated too ambitiously.

Section 10.5 Acids and Alkalis

This is introduced at a purely observational level, pupils being asked to test a whole range of substances with pH paper and to record the colour change in each case. The use of small bottles fitted with a pipette arrangement to allow for "spotting" on to the pH paper will be found convenient and economical in materials. A chart of the pH values associated with the different colours observed should be clearly available to the class. Some members of the class might investigate the change in pH resulting from the dilution of a solution of dilute hydrochloric acid or dilute caustic soda but at this stage no explanation is expected. The main aim must be to familiarise all pupils in the group with the use of a pH scale and to show them that the same scale can be used for acidity and alkalinity.

Neutralisation

The changes in pH, when an acid solution is added to an alkaline solution, can be readily observed, and pupils are normally fascinated by watching the colour changes in universal indicator which can be brought about by alternate additions of acid and alkali to water containing a few drops of the indicator. The question can then be posed - is it possible to obtain a neutral stage (pH 7) where the acid and alkali have apparently "cancelled out" each other? After initial observations of this type a simple "titration" experiment can be carried out. 10 ml of dilute sodium hydroxide (approximately 2 M) is measured into a test-tube, using a graduated beaker or a small measuring jar or a syringe (suitable syringes are now commonly available), and the pH of the solution noted after the addition of a few drops of universal indicator. The pH of a sample of dilute hydrochloric acid (approximately 2 M) is now determined. Using another syringe, 1 ml of this dilute acid is added to the 10 ml sodium hydroxide and the pH is again noted. Repeated additions of 1 ml of dilute acid are then made, the solution stirred after each addition and the pH noted. This is continued until the solution is definitely acidic. With abler pupils a graph of pH against the volume of acid added can be drawn. The volume of acid required to produce a neutral solution is noted. The molarities of the acid and alkali need not be the same but should be chosen so that a convenient volume of acid has to be added to achieve neutrality. Thus in this case a volume of acid between 8 ml and 12 ml would be suitable. No high degree of accuracy is expected in such a procedure but it should be possible to obtain the volume of acid required to the nearest 1 ml. Examination of class results should convince the pupils that the given volume of sodium hydroxide solution always requires the same volume of the given hydrochloric acid for neutralisation. Using another 10 ml of the same sodium hydroxide solution but without universal indicator, the volume of hydrochloric acid now known to be required for neutralisation is added. The taste and pH of this solution should then be compared with the taste and pH of a solution of sodium chloride - a solution of comparable concentration should be used. The neutral solution can also be left to crystallise producing crystals of "common salt" and in class discussion the general point can be made that when an acid and an alkali "cancel out" or neutralise each other then salts are obtained. If time is available other "titrations" can be carried out to produce salts such as potassium nitrate and sodium sulphate, which can be isolated by crystallisation. Neutralising barium hydroxide with dilute sulphuric acid or calcium hydroxide with a solution of carbonic acid will of course produce insoluble salts. Faster pupils might be asked to observe any temperature changes occurring during neutralisation and to interpret their observations. A valuable extension of this work is the measurement of the pH of various soils, using some simple form of soil tester, and pupils might be asked to collect suitable samples. These investigations could lead to the necessity for adding lime to certain types of soils and some pupils could be asked to devise experiments to determine

whether in fact lime does neutralise acid solutions. The Nuffield guide, Chemistry - The Sample Scheme Stages I and II, describes on page 136 an experiment in which pupils follow the change in pH when slaked lime is added to vinegar.

Further work on neutralisotion

The class results obtained by use of simple "titration" techniques with syringes (or graduated beakers) should be accurate enough to convince pupils that a given volume of alkali requires a fixed volume of an acid solution for its neutralisation. For some pupils the consideration of neutralisation will stop at this stage but with abler pupils it should be possible to extend the argument. If the alkali solution is diluted, say with an equal volume of water, will the volume of the given acid required for its neutralisation be more or less, or will it remain the same as before? Pupils should be able to predict a reasoned answer to such a question before carrying out experimental work to check their predictions. Worksheet number 10.7 suggests a suitable procedure but, as always, pupils should be encouraged to suggest and try their own approaches. Similarly if the acid solution is less concentrated, will more or less of the diluted solution be required to neutralise the original volume of alkali or indeed will the same volume still be required? Pupils can investigate this problem for themselves, various groups diluting the given hydrochloric acid with different volumes of water to produce a range of acid concentrations. In the discussion of these and similar experiments attention should be focussed upon the masses of alkali and acid present in the various solutions, and it should be possible to establish that in neutralisation reactions a fixed mass of acid will neutralise a fixed mass of alkali irrespective of the volumes of the solutions involved.

IV References

Nuffield guide, Chemistry - The Sample Scheme, Stages I and II.

Chemistry takes Shape, Book I and Teachers' Guide, Chapter VI, Johnstone and Morrison, Heinemann.

SECTION 11 - DETECTING THE ENVIRONMENT

I Introduction

The ability to receive and react to stimuli from the environment is one of the basic characteristics of living things. The aim of Section 11 is to introduce the pupil to the receptor mechanisms of the human mammal, and to the limitations of these receptors.

The experimental work is simple but enjoyable and stimulating to the pupil. The physics of optics and sound are introduced primarily as a necessary background for the understanding of the biology of seeing and hearing. This background requires costly apparatus, eg ray boxes, signal generators, C.R.O.s etc, but these are usually available in the physics department. Otherwise the apparatus is simple, and most of it can be produced from readily available materials in the laboratory.

The section is not necessarily set out in a teaching order, though it can be used in that way. It is, however, most successful in stimulating discussion and a desire for further investigation if one begins with some little experiments which illustrate the eye at work. The pupils will themselves suggest investigation into structure, in an attempt to explain their experimental experiences. A study of the ear structure can be approached in a similar manner, and such an approach does achieve maximum involvement of the pupils. Since the pupil is the basis of the experimentation, it is relatively simple to stimulate discussion on how man has overcome some of the limitations of his senses, and to point out that instruments are extensions of his sensory mechanisms.

As in previous sections there is much opportunity of experiencing *scientific method*, which can be thought of quite simply in terms of confronting ideas with experience, ie forming hypotheses and designing experiments to test them.

II Specific Objectives Pupils should acquire

1. knowledge of some facts about the human eye
2. knowledge of some facts about a pinhole camera
3. the knowledge that the focal distance of a lens is related to its curvature
4. knowledge of some facts about a lens camera
5. the knowledge that the brain does not always interpret the signal from the eye correctly
6. ability to make comparisons between related entities (eye and camera)
7. awareness of the importance of knowing that the brain may not interpret the signal from the eye reliably
8. awareness of our reliance on binocular vision for many judgements
9. some skill in the use of simple dissecting instruments
10. knowledge of the major parts of the ear (drum, bones, inner ear)
11. knowledge of the operation of the bones of the inner ear
12. the knowledge that the production of sound requires a vibration
13. the knowledge that pitch is related to frequency, which is related to length of vibrator and tension in vibrator
14. the knowledge that a medium is needed for transmission of sound
15. the knowledge that the ear has a limited band of reception
16. ability to use inductive processes of thought to build the hypothesis that vibrations are necessary for sound to be produced
17. ability to draw conclusions from a variety of data obtained in finding threshold frequencies for the ear
18. awareness of the receptors of communication and man's dependence upon them.

III Experimental Details

Section 11.1 The eye and light

Dissection of the eye

Instructions may be obtained in Nuffield Biology Text IV page 171. Bullocks' eyes may be obtained in quantity from a slaughterhouse.

The lens should be examined not only to show its relation to a glass convex lens but also so that the shape may be altered.

Now that the motivation has been supplied it is appropriate to begin a study of some simple optics. Note that throughout this course the teaching order has been based upon psychological rather than logical grounds. The start of a science syllabus was formerly taken to be a logical series of measurements of length, volume, mass, density ...; the logical way to study electric circuits was to start with simple cells; and the logical start to a study of gases was to prepare them in the laboratory.

This course accepts that pupils do not have the benefit of our hindsight and are more likely to be motivated by, and therefore to profit from, a course which takes into account their age and interests. We introduce the course with a "romp" section which involves measurement in the by-going; electric circuits are studied, assuming that a cell supplies us with electrical energy; gases are taken from cylinders-and now optics is introduced via the eye.

The Nuffield Physics Guide to Experiments no III has a valuable section, in experiments 6-24, part of which is of relevance here. Particular experiments are no 7 on the pinhole camera; no 10, image formation using a lens; parts of no 14, rays of light and cylindrical lenses; and no 22b, model eye.

NB There are few worksheets supplied on this section and it is intended that the teacher should provide lessons to fill out the material, eg with important applications such as the camera.

Section 11.2 Vision

It is intended that this series of interesting experiments should be carried out by the pupils, either as "P" or "S" experiments, ie by the groups doing either the same experiments or different experiments at "stations".

Judging distance with one eye

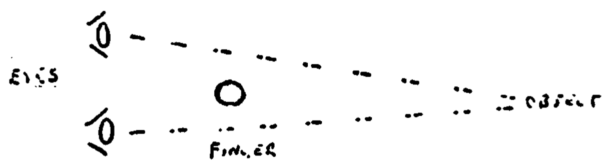
One pupil extends hand, closed except for index finger pointing upwards. Second pupil faces first, with hand well out in front, and index finger pointing downwards. Second pupil closes left eye, and advances, to bring finger down on top of first pupil's finger. Repeat with both eyes open.

Or singly

Hold out bottom end of pen at arm's length. Close one eye. Bring cap from behind your back, and put it on bottom end. Repeat with both eyes open.

Distinct images of two eyes

a. Hold an object upright about 50 cm from the face at eye level. Focus on this. Still looking at the object, place the forefinger of the other hand between the eyes and the object.



Note the double image.

Overlapping images

a. Extend both arms in front of you with the index fingers pointing inwards. Look into distance, beyond the fingers. Bring index fingers together until they touch, keeping the eyes still focused in the distance. Now separate the fingers.

Note the floating extra "finger".

b. Look at cyclist with the left eye and the lorry with the right eye. Bring the page slowly nearer to your face.

Note the effect - the cyclist "moves" to the right.

Range of Vision (in pairs)

One pupil focuses on a distant object. Second pupil holds a pencil in front of the first pupil's eyes, and gradually moves it to one side until it is lost to sight of first pupil.

Repeat on other side, upwards and downwards.

Blind Spot

Either usual X and dot, or Nuffield Biology Text IV P. 171.

The latter is often more successful than the former.

Colour vision (in pairs)

a. Stand behind your partner who looks forward and "fixes" on a distant object. Bring different coloured cards from behind gradually towards the front, keeping the same distance from the eye.

At what point is "subject" aware of the card?

At what point is *colour* noted?

Are these points the same?

Which colour is most quickly seen?

This experiment should illustrate that colour is not observed peripherally, and that yellow is most quickly seen. Reference might be made to the "safe" colour for cars, and the change to yellow for fire engines etc.

Colour blindness

b. Ishihara test cards for colour blindness can be used here, as a class experiment. It is possible to detect colour blindness in a pupil.

Persistence of retinal impressions

Use cards with a goldfish on one side and bowl on the other (or bird and cage). Suspend cards by a thread so that they can be rotated rapidly. Or make "books" with several small sheets of paper stapled together, each sheet having a slightly different drawing, eg cat and mouse. Rapid flicking should show cat catching mouse.

Optical Illusions (See Tolansky's book, Optical Illusions, Pergamon.)

Most of the experiments in section 11.2 take only a few minutes, and can all be conveniently covered in one double period lesson.

Section 11.3 Ear and Sound

This section starts again with the pupil himself. The structure of the ear gives rise to questions concerning sound energy, its source and transmission.

Sources of Sound

Pupils are asked to bring along and demonstrate one source of sound each. Some suggestions are: tapping with ruler on bench top or radiator, tin lid, milk bottle etc, rustling of newspaper, shaking pebbles in syrup tin, "twanging" a ruler, elastic band, blowing across the top of a medicine bottle. Some musical instruments could be brought along as well.

The class should be encouraged to listen to sounds in their own environment and interpret what they hear. They discover noise and rhythmic sounds and proceed to study the more pleasant musical sounds in detail. Vibration and sound are associated.

A series of stations experiments can then be investigated.

Clamped rulers of various lengths are "twanged". Long ones vibrate slowly - a low pitched note may be heard or perhaps no sound at all will be detected. Short ones vibrate faster to produce a high pitched note. Stretched elastic bands are plucked - vary tension - observe vibration if possible and pitch of note. Study set of tuning forks - massive ones produce low notes etc. Touch water surface and suspended pith ball with sounding tuning fork - vibration detected. Blow across top of medicine bottled filled to various levels with water, also tap them with a ruler. Feel throat while talking or singing.

Demonstrate with a bristle on prong of sounding tuning fork, rapidly drawn across a smoked glass plate to show vibration of prong - a discussion should elicit that vibrating bodies produce sound. The faster they vibrate (frequency) the higher is the pitch of the note heard. The larger the vibrations (amplitude) the louder is the sound. We do not hear sounds associated with very slowly vibrating bodies (lower limit). Is there an upper limit?

A large-scale demonstration (eg 100 pupils) using C.R.O., signal generator and loudspeaker to determine the upper threshold should be carried out, and a statistics board used to plot a distribution curve (see film "Science for the '70s"; Scottish Central Film Library).

Medium

Electric bell in vacuum - a well known experiment. (Physics is Fun II page 75, Jardine, Heinemann.)

Listen to ticking of a clock through a wooden rod (stethoscope) - pin a disc of cardboard to each end of rod to prevent pupils putting the rod in the ear. Use a string telephone. Place watch on forehead - ticking heard by bone conduction. Fill plastic bag with water and listen to ticking of watch through the bag.
A discussion of sounds heard by swimmers, trackers with ear to ground, prison grape-vine via water pipes etc, should serve to consolidate this lesson. Pupils conclude that sound requires solid, liquid or gas (a material medium) through which to travel.

Section 11.4 Balance

It is worthwhile doing a few experiments on balance, since they bring out clearly the need for more than one external signal.

a. In pairs.

Ask partner to stand steady on one leg for two minutes. Now ask partner to close eyes and remain steady for a further two minutes.

b. Spin pupil, with eyes closed, on chair. Stop chair, and ask pupil if he is still spinning.

Now tell pupil to open eyes, and note direction of room.

c. Semicircular canals. See experiment on page 180 of Nuffield Biology Text IV.

Model of semicircular canals - SSSERC design.

Section 11.5 Taste, Smell etc

Taste

Solutions of quinine sulphate, sucrose, sodium chloride and citric acid (0.1 g to 5 ml water) should be prepared.

Pupils, working in pairs, place one drop of the solution in turn on different parts of the extended tongue. The tongue should remain extended during the test, and the mouth rinsed between the tests.

The pupils should then fill in a "map" of the tongue, normally:

Smell

In pairs.

a. One pupil is blindfolded. Other holds a piece of apple to nose of partner, and places a piece of potato in partner's mouth.

or

b. One pupil's nose is held and he is blindfold. Partner places various pieces of food eg apple, potato, onion on extended tongue.

These experiments should illustrate that taste is limited and that "taste" is often really smell. Refer to "tasteless" food when suffering from a heavy cold. It is also instructive to refer here to the fatigue of the sense of smell, eg to perfume.

Skin

Since the aim is to study sensory receptors, structure of the skin need not be dealt with here. It is sufficient to show by experiment that there are different nerve endings for the sensations of heat, cold, touch and pain.

In pairs.

Apparatus:- 2 wooden handled seekers
1 beaker of ice
1 beaker of hot water

'Subject' rests arm on bench, palm down. A square is marked on forearm just above wrist. 'Subject' should closy eyes. One seeker (hot or cold) is taken, dried on tissue, and then touched on marked area of arm. 'Subject' should state each time what is felt, if anything, ie heat, cold, pain or touch. A map of results should be made, using letters H, C, P, T.

Double touch sensations

In pairs.

Apparatus:- Dividers or 2 straws with stiff bristles.

'Subject' closes eyes. Partner touches lightly sometimes with two points, sometimes one, on various parts of body, eg back of neck, forearm, back of hand, finger tips, lips, palm. Pupils should find that touch receptors are farther apart in some areas than in others, eg about 5 cm on back of neck, and very close on tips of fingers.

These experiments and discussion can be completed in one double period or less, and the lesson finished by showing that we cannot rely on our nerve endings for estimating temperature. Alternatively the following experiment can be carried out as homework by the pupils.

Apparatus:- 1 bowl hot water
1 bowl cold water
1 bowl tepid water

Pupils place one hand in hot water, and one in cold water for a few minutes, then transfer both at once to tepid water, and note sensation in each hand.

Reflex actions

A simple idea of a reflex arc can be given, using the knee jerk reflex as a pupil experiment. It is important to show that resistance will not stop reaction, and to emphasise that reflex action is an immediate automatic response to a stimulus, which is inborn.

Other reflex actions can be discussed in class at this point, or a homework exercise to list other reflexes given. It should be emphasised that inborn reflex actions are usually concerned with preservation of the individual.

Reaction Times

1. This can be done as a class experiment.

All stand in a circle, eyes closed, one pupil holding a stop watch. This pupil should start watch as he taps next pupil on shoulder. The tap is passed round circle until it reaches first pupil again, and watch is stopped.

If this is repeated several times, it will be noted that the time taken can be reduced.

2. In pairs.

Apparatus:- A graduated lathe (pattern obtainable from SSSERC) or card (from Society for Prevention of Accidents). The latter has amusing remarks at each point which enlivens the experiment.

Subject has to grasp falling lathe. Again, repeat several times and note improvement in performance.

These exercises can lead to a short discussion on conditioned reflexes (eg Pavlov's dogs) and on learning.

Some pupils might like to try experiments at home or in the laboratory with fish, eg tapping aquarium (or shining a torch) each time fish are fed.

An exercise could be given on listing some conditioned reflex actions.

The brain and spinal cord

From the foregoing work, the pupils will have learned that "messages" must travel to and from centres of control, that some reactions are controlled by will, and that others are involuntary. They are now ready to examine a model brain. Only the main areas and functions should be given.

This section, from Reflex Action, can be covered in one double period since the experiments take very little time.

IV Homework Suggestions

List parts of a camera. Pupil to write opposite the comparable parts of eye.

Thread needle, using both eyes. Thread needle, using one eye.

Collect optical illusions.

Experiment to show that nerve endings in skin are unreliable in estimating temperature. If this has been done in laboratory, it can be extended by asking pupils to compare sensations from fingers and from elbow in same bowl of warm water.

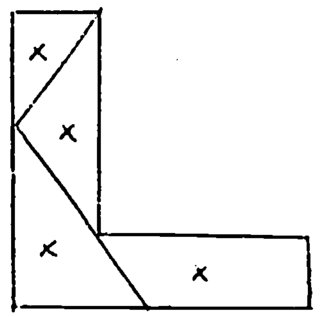
List reflex actions, and try to show the path by diagram.

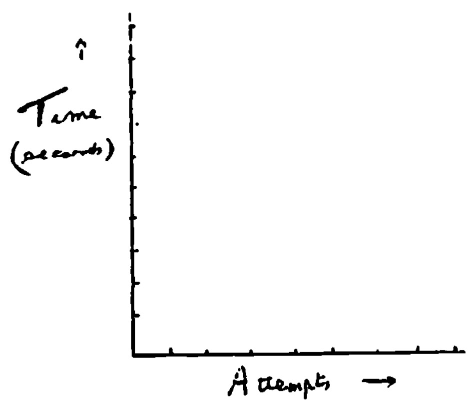
List conditioned reflexes.

Pupils to devise an experiment to establish a conditional reflex in a domestic pet. If pupils have pets, they might carry out experiment and report results.

Issue cards of letter L cut in four pieces. Pupils to assemble four parts ten times in quick succession, noting the time on each occasion. They repeat this thirty minutes later.

They should graph the results.





V References

1. Buffield Biology Text IV, Living things in action, Longmans-Penguin.
2. Nuffield Physics Guide to Experiments, III, Longmans-Penguin.
3. Simple Experiments in Biology - Cyril Bibby, Heinemann.
4. Biology by Inquiry, Volume 2, Clarke et al, Heinemann.
5. Introduction to Biology, Mackean, Murray.
6. Optical Illusions, Tolansky, Pergamon.

Reaction Time Card

Royal Society for Prevention of Accidents
52 Grosvenor Gardens
London SW1

VI Films

You and Your Eyes (colour)	- G225	10 minutes
You and Your Ears (colour)	- G226	8 minutes

See part of Esso-Nuffield teachers' film "Experiments in Ray Optics".

SECTION 12 - THE EARTH

I Introduction

This section is essentially informative. In the past it has not been customary in the school science course to consider the nature and importance of the earth itself, and yet it represents by far the greatest part of our environment.

It is not intended that a detailed explanation of the structure of the earth in geological terms should be given, but rather that the pupils should be made aware of the existence of the common compounds which make up the earth's crust, and that they should discover some of the reasons for their existence and continuing presence.

The economic significance of coal and oil as sources of energy and the importance to a highly developed civilisation of the winning of metals from their ores should be discussed at every opportunity.

It is one of the general aims of this course to expose the pupils to some of the fundamental cultural aspects of science, and this section provides a good vehicle for this purpose in the first two years. The significance of metals in the history of man is clearly related to the ease with which they can be isolated; the present search for other metals as new and more exacting specifications are demanded; and the economic importance of such developments to the nation can all be incorporated in the class discussions which will arise during this work. Such discussions are equally possible in connection with silica and silicates as refractories and building materials, and in dealing with coal, gas and oil as the traditional sources of energy. The emerging importance of the sea as a reservoir of metals and of energy should not be ignored.

From considering the earth as part of the environment in which *we* live, we move to a study of the soil as the total environment in which *other* organisms live. Here we are concerned with the interrelationships of the different elements within an ecological system as much as with specific information about the animals and plants of the soil.

A spadeful of soil from the garden is a mini-world all of its own in which the different elements are all interdependent, just as man in his environment is dependent on and affected by all the other elements which compose that environment. This last part does provide a training in the techniques used in investigating an eco-system. It equally can be applied to any other single system such as the rock pool, the fresh-water pond, etc.

At the beginning of this section pupils should be encouraged to bring in samples of local rocks, and should try to name them with the aid of a suitable book on minerals which has plenty of coloured illustrations.

Classification of rock specimens is not an easy matter as materials are seldom pure; silicate rocks are particularly difficult, and these are the most common. It may only be possible to classify them according to type.

NB It is important that these sections of the work, in the middle of year II, should not be drawn out unduly. Priorities should be decided upon - eg how important is it that sections 13, 14 and 15 are completed, in order to round off this introductory cycle. Long-term planning is necessary in order to avoid an unbalanced course.

II Specific Objectives Pupils should acquire

1. knowledge of some facts about the origin and structure of the earth
2. knowledge of some facts about naturally occurring elements and ores
3. knowledge of the reasons for the presence of these elements and ores in the earth
4. further knowledge of the idea of order of activity in elements
5. knowledge of some facts about silica and silicates
6. knowledge of possible means of forming metamorphic rocks
7. some information about colours in minerals and glazes
8. some information about the fossil fuels (coal, oil, and natural gas)
9. some information about the salts of the sea
10. knowledge of some facts about the soil
11. knowledge of some facts about micro-organisms
12. ability to form hypotheses from experimental observations, using data derived from experiments on oxides, sulphides and carbonates
13. ability to retrieve information about earth, fossil fuel, rock types, etc
14. ability to use acquired knowledge and skills in solving a problem of identification of an unknown substance, malachite. (This involves both analysis of material to obtain information and a synthesis of the findings to provide a reasonable solution)

15. further ability to use a key in identifying unknown creatures
16. awareness of the importance of certain properties of minerals in the earth, which allow them to be used for building materials
17. interest in the need for conservation of fuel resources
18. awareness of the importance of the sea as a source of mineral
19. awareness of the place of micro-organisms in the life of man, both useful and harmful
20. various chemical and biological skills
21. some simple micro-biological techniques

III Experimental Details

Section 12.1 Origin and structure

Section 12 opens with a *brief*, and, of course, much simplified discussion of the origin of the earth. It is not intended that much time should be spent over this. It is sufficient to point out that the earth was originally molten and that, on cooling, solids crystallised out.

The idea of crystallisation from a melt may need revision - some pupils find it easy to understand crystallisation from a solution, perhaps because this is more their experience, but do not readily accept the idea that molten substances crystallise on cooling. If this is so, experiments may be carried out on the crystallisation of molten sulphur, naphthalene, or potassium dichromate.

This leads straight into igneous rocks. Some crystalline specimens should be available, eg quartz, mica, felspar, granite (a mixture of the preceding three in which crystals of all can usually be seen). A geological map of the British Isles should be shown and the distribution of igneous rocks should be examined. Some correlation with geography should be effected here.

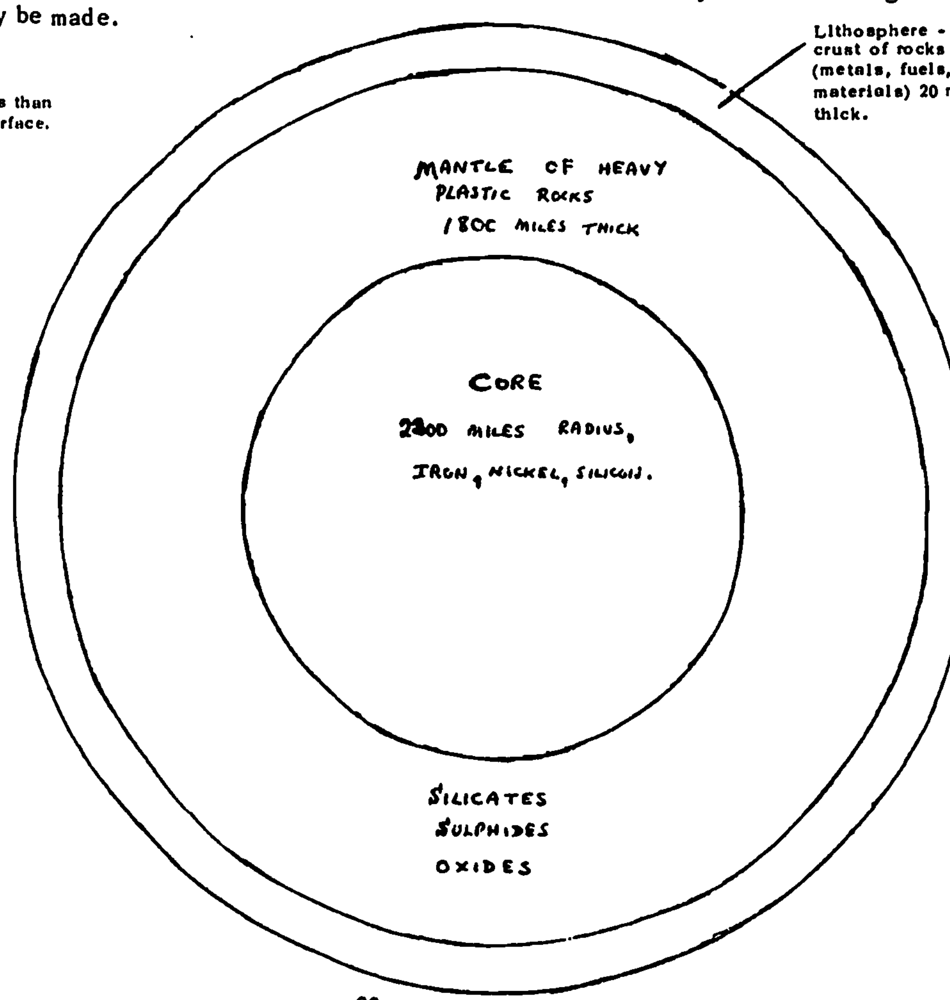
A brief discussion of weathering is desirable to introduce sedimentary and metamorphic rocks. Again samples should be available, and a comparison should be made with igneous rocks on such points as hardness, ease of powdering, etc.

The existence of strata should be shown if possible by visits to local quarries, railway cuttings, etc. If there are no features of this kind near the school, slides can be shown. Charts should be displayed showing the thickness of the crust, and reference should be made to the "Mohole Project". A drawing such as that given below may be made.

Structure of the Earth

Atmosphere - 98% is less than 40 miles from Earth's surface.

Lithosphere - light crust of rocks (metals, fuels, raw materials) 20 miles thick.



Emphasise that we do not have specific information about the structure of the Earth - the deepest mines go only three miles down and the deepest oil wells at most five miles.

It is useful to draw attention to the fact that comparatively few elements are represented in the earth's crust.

	Percentage by weight approximately
Oxygen	46
Silicon	27
Aluminium	8
Iron	5
Calcium	4
Sodium	3
Potassium	3
Magnesium	2
Hydrogen	1

(It should be pointed out that these elements, except oxygen, of course, do not occur *free* but in the form of compounds.)

The above nine elements account for about 99 per cent by weight of the earth's crust and are all comparatively light. Most of the elements that we use in everyday life are not very common, and some are quite scarce.

As mentioned above, there may be considerable overlap in this section with geography; if the work has been covered in the geography department there is no need to go over it again.

Geologists should beware of the temptation to take this section too far!

Section 12.2 Naturally occurring elements

Open the discussion by asking the pupils to write a list of elements which they know occur naturally. It should contain the following.

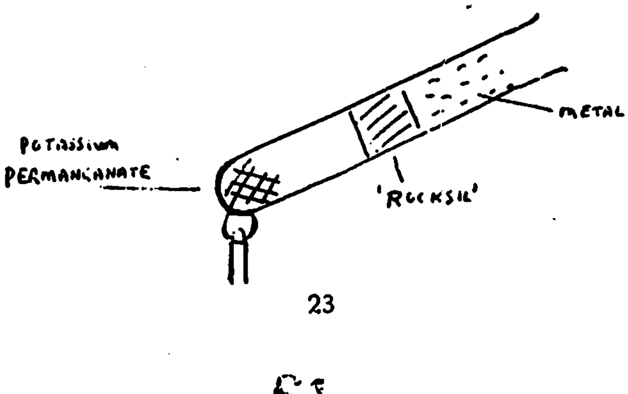
Copper)
Silver) - These are comparatively rare.
Gold)
Mercury)
Iron

Oxygen
Nitrogen
Carbon
Sulphur

The inclusion of iron raises some difficulties. It is almost all of meteroric origin and is not pure iron. The impurities, mainly nickel, are such as to make it rustless.

Can we find out why the list does not contain elements such as magnesium, aluminium, lead, zinc or tin? Ask for a hypothesis in the hope of getting the answer - if they did exist at one time they would have combined with other elements by now (rusted away etc).

Experiments on the action of oxygen and sulphur on metals should be carried out to show the energy evolved in these reactions and to provide a basis for an explanation of their non-occurrence in nature. The simplest method is the "Arcalus" method. Oxygen is generated by heating potassium permanganate at the foot of the test-tube. A loose plug of *dry* glass wool or "rocksil" is placed above the permanganate and beyond this the metal.



The metal is heated first, then the permanganate is gently heated, the flame being moved backwards and forwards to keep both the permanganate and the metal hot. Magnesium should be used in the form of ribbon, aluminium as thin foil, iron as filings, zinc as filings (zinc dust is often well coated with oxide and does not give satisfactory results), tin as thin foil, copper as turnings or powder, and silver as thin foil.

An attempt should be made to place the metals in order of activity with respect to oxygen. This can be done roughly be estimating the order of vigour of the reaction. Although this experiment may be done as a class project, different groups using different metals, it is necessary for all to see each experiment, otherwise comparison is not possible. The order of activity arrived at should be Mg > Al > Fe > Zn > Sn Cu > Ag.>

A similar experiment can be carried out with sulphur. The sulphur is used in place of permanganate, and only a *thin* plug of glass wool or rocksil is required. If too thick a plug is used, sulphur vapour will condense on it, and it will not reach the metal. The plug should be heated as well as the reactants.

NOTE. It is important that mixtures of *powdered* metal and sulphur should *not* be heated. The reaction can be explosive.

The results of this experiment indicate that many metals combine with sulphur and that some combine more readily than others. A rough order of activity should be arrived at in the same way as for oxygen. This is known as the activity series, and later in the certificate course it will be developed more accurately as the electrochemical series.

Section 12.3 Naturally occurring sulphides, oxides and carbonates

The most common minerals are oxides, sulphides and carbonates. Examples should be available, possibly collected by the pupils. Several chemical suppliers sell sets of minerals. Pupils should handle them and test their hardness and solubility.

When sulphide or carbonate minerals are heated in air, they are generally converted into oxides. An example of this is the heating of iron pyrites in air. Powdered iron pyrites can be heated in a small test-tube; sulphur is seen in the tube, and the residue looks rusty. The experiment can also be carried out by heating on a piece of asbestos paper. The problem is how to get the metal from the oxide. Recall the readiness with which metals combine with oxygen. To get oxygen away from its compound with the metal we shall have to use an element which has a stronger "pull" on oxygen than the metal has. Pupils will know that such elements are hydrogen and carbon. Hydrogen *could* be used, but is not very convenient, so we shall try to remove the oxygen by using carbon. A simple way of carrying out this experiment is to heat a mixture of the oxide and charcoal on a piece of asbestos paper. Various oxides should be tried (including those known to the teacher not to be reduced), and the results shown to agree with the activity series.

From these experiments pupils should readily see why copper and iron were the first metals worked by man, whereas magnesium and aluminium have come into use only comparatively recently.

The effect of heating, and adding dilute hydrochloric acid to, the carbonate minerals chalk and magnesite should be examined and the gas evolved should be tested with lime water. With the experience of this work behind them the pupils might now be given some malachite (or powdered copper carbonate) and asked to investigate it for themselves. The faster pupils should be able to do this with very little help; the slower ones may need to be given some pointers.

Section 12.4 Silica and silicates

Silica and silicates are included in the syllabus because they are the most abundant of all rocks, and because of their importance as the basis of glasses and building materials. It is not expected that the chemistry of the silicates will be studied, but the following points should be made by means of appropriate experiments:

1. The silicate rocks are refractory. The action of heat on various silicates should be examined. Sand, clay, and any local silicate rock can be used.
2. Silicates are not affected by common acids.

It is interesting to make various insoluble silicates by means of a "silica" or "chemical garden". Water glass (commercial sodium silicate) is dissolved in water (about 20 g in 100 g water) and small crystals of the sulphates of copper, nickel, chromium, cobalt, manganese, iron (II) and iron (III) are dropped in. The solution is left undisturbed, when coloured plant-like growths of the metallic silicates form.

To illustrate the metamorphic effects of heat on silicates, clay from the Art department may be moulded into small tiles and fired in the potting kiln. This illustrates the formation of bricks. The tiles can then be used for glazing. Some can be dipped in salt solution and re-fired. Others might be treated with colourless glaze from the Art department. A crystal of various salts (such as those used in the "chemical garden" experiment) may be placed, one at the centre of each tile, and the tiles can be fired. Various coloured glazes are produced.

Commercial glazes usually melt at a temperature higher than that which can be obtained with a blow-pipe flame in the laboratory. (They are also lead-free for health reasons.) A good glaze mixture which will fuse fairly readily can be prepared by grinding together 2 g red lead, 2 g sodium carbonate (anhydrous) 1 g powdered flint and 0.5 g cobalt nitrate. Water is then added to the mixture to make a smooth paste and is then painted on to a pottery tile, or a piece of porous pot. The mixture is then evaporated by heating gently, and then the piece of pottery is heated strongly in a blow-pipe flame or in a muffle furnance if available. A deep-blue glaze is formed.

Different groups of pupils may try the effect of substituting 0.5 g of other transition metal nitrates, or mixtures of them, in place of the 0.5 g of cobalt nitrate.

Section 12.5 Coal

The origin and the types of coal found in the British coalfields (together with lignite) should be discussed and illustrated. The distillation of coal and the value of the products obtained can be dealt with and a simple experiment carried out to illustrate the processes of coal gas making. Both aspects of the topic can be greatly enhanced with illustrative material issued by the National Coal Board and the Gas Council. (Teachers are well aware of these generous sources of material.) The fact that coal, once the chief source of Britain's wealth and power, is fighting a battle with imported petroleum should be noted. Although our coal resources are dwindling and the seams are now hard to get at, improved techniques of mining are making the battle against oil a long drawn out one. The pupils should realise that two world wars started the economic war between coal and oil, by causing the evolution of the motor car and aircraft to be vastly speeded up.

Further details

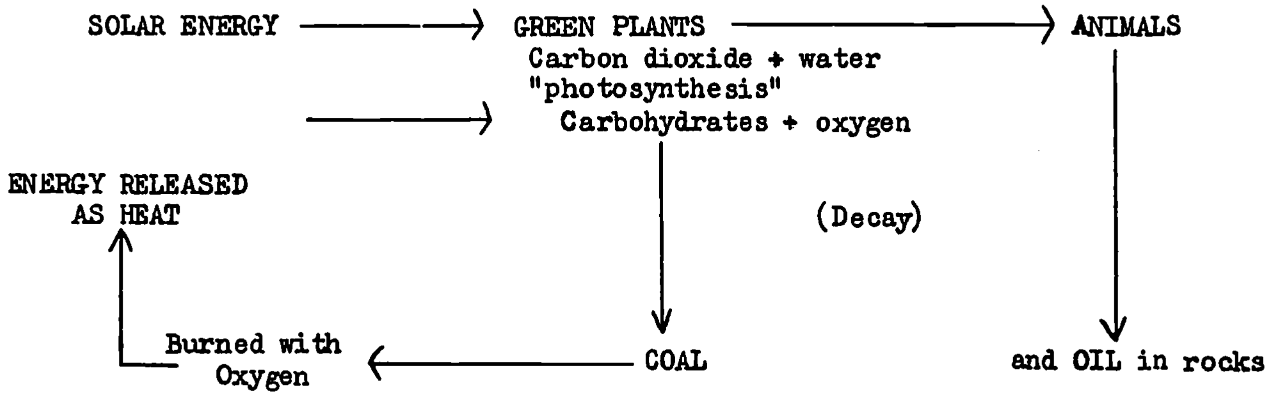
1. Examination of charts showing origins of coal. Examination of specimens of peat, lignite, bituminous, cannel and anthracite coals.
2. Dry distillation of coal. Pupils should be asked to bring a coffee or similar small tin, together with fragments of coal. These should be ground up to particles the size of wheat grains and placed in the tin. A hole is then punched in the lid with a nail. The lid is then tightly replaced. The tin is now placed upon a tripod stand and heated. Soon yellowish fumes issue. This is crude coal gas. It may be ignited and will burn with a yellow, luminous flame.

   A much more refined model gas works may be set up with boiling tubes as retort and condensers. The pupil is likely to be much more excited by what he has brought along himself. As a result he may become much more knowledgeable about the principles being investigated. This section would not be complete if reference were not made to air pollution and the new act of Parliament designed to eliminate this menace to the nation's health.

Section 12.6 Oil

Most children understand how coal was formed from decayed plants that grew in swamps or on land that became swampy in the Carboniferous Period of geological time. They are less certain about the origin of petroleum deposits. These formed from the accumulated decayed remains of sea animals and plants that settled on the muddy floors of ancient seas. As the muds hardened into rocks, the oily organic material migrated upwards. Some indeed reached the surface and eventually, through evaporation of the more volatile material, formed tar lakes like that in Trinidad. Much of it was trapped by impervious rock in various ways. The trapped deposit usually comprised natural gases that separated off above the oil, the oil layer and then water. The oil has to be extracted by drilling and usually has to be pumped to the surface. Only then can it be separated into the great variety of closely related chemicals that we call hydrocarbons so much a part of life today. Indeed the processes of distillation, described in section 5, have to a large extent been complemented today by "cracking" of the hydrocarbon mixtures to yield materials more closely related to our present-day needs.

It must be emphasised that the plants and animals of so very long ago grew by utilising the sun's energy. In burning these fossil fuels we are releasing again the solar energy that was trapped and stored millions of years ago:-



This can be linked up with section 3.

There is so much visual material offered to the teacher by all the large petroleum refining and marketing organisations that it should be possible to make a really interesting display out of the subject.

A number of films, film-strips, and books are also available from these sources.

Further details

1. Examination of charts showing the origin and methods of extraction of petroleum.

   Examination of charts showing the refining of petroleum.

   Display of petroleum geology materials.

   Crude oil samples and the refined products from this.

   By-products of the oil industry, such as plastics and detergents, may be displayed, but these topics are more appropriate to section 13. The film strip, "Oil from the Earth" by Shell International Petroleum, could now be shown with advantage.

   The illustrated booklet, "Petroleum in Pictures", by Shell-Mex and B.P. is made available in quantity to schools and will provide a valuable background of knowledge gained through home reading.

2. A fractional distillation of a sample of crude oil is easily carried out in the laboratory and gives a very authentic atmosphere to the work. Crude oil can be purchased from chemical suppliers.

   A filter test tube with the usual side-arm is the basis of the experiment. It is fitted with a 0-300°C thermometer, using a good fitting cork stopper (rubber "swells" rapidly in contact with crude oil), and with a slight bent delivery tube about 25 cm long which makes a satisfactory air condenser. About 10 ml of crude oil is introduced into the filter tube. A lightly compressed wad of asbestos wool is then tamped into place about an inch above the crude oil. Distillation is then proceeded with. The fractions are collected in smaller test tubes. "Cuts" in the distillate are made at approximately 0.5 ml intervals. The small test tubes are stoppered and labelled and may be stored in a stand made by drilling suitable sized holes in a small wood block. The first cut should smell of petroleum ether, the next of petrol, the third will be light lubricating oil, and the last fraction will probably be a wax. The "still" may be washed clean with benzene and can be used many times. It is interesting to test each "cut" for flash point or ignition temperature by pouring it into an evaporating basin and applying a lighted match or taper.

Section 12.7 Salts from the Sea

It is surprising that many science courses ignore the sea, which is a vast store-house and source of so many chemicals. And this is so despite the fact that common salt, a natural product of the sea, is of vital significance to man. It is necessary in the wider sphere as an essential mineral. It has for long been a starting point in school chemistry for investigations of crystal structure, of molecular structure and of chemical bonding.

The saline content of sea water owes its origin in part to the land through the leaching process which follows the weathering of the rocks of the earth's crust and secondly to the direct solution of the minerals in the rocks beneath the vast oceans themselves.

For the examination of sea-water we shall require some litres of fresh sea water from the open sea (as opposed to tidal river water). This water has a rich and varied biological life which can form the basis of an interesting study in itself. It will not keep but tends to putrefy when stagnant.

The addition of thymol crystals to a little of this water, which can then be warmed to dissolve them, will provide a means of preventing putrefaction of the main stock of sea water without affecting the success of future investigation.

We now proceed with the evaporation of a large volume of sea water in a beaker. Here we are duplicating an age-long process in miniature. It is noteworthy that one such litre at 25°C weighs 1025 grams and contains 990 grams of water and 35 grams of salts. The salinity of sea water, based on these figures, is 34.48 grams per litre. The pH at 15°C is 8.1, showing that sea water is alkaline. This excess of hydroxyl ion is due to the hydrolysis of calcium bicarbonate.

This evaporation should be begun in advance of the pupils' experiments, and should be continued as a background to them. First the large beaker is graduated into 100 ml divisions upon a strip of paper gummed to the outside wall. It is now filled to the litre mark with filtered sea water. Evaporation upon a sand tray at around 95°C is begun. The class should see the preliminary operations and the attention of the pupils should be drawn to interesting stages in the testing. When the liquid has been reduced in volume to 300-250 ml, it is allowed to cool, so that the cloudy precipitate settles. The liquor is decanted from this. A few drops of dilute hydrochloric acid will release a gas that causes lime water on the end of a glass stirring rod to turn "chalky". The residue held on the end of a platinum wire of clean iron wire drawn from a thin wire gauze will impart the brick red coloration to the bunsen flame that denotes calcium.

The mother liquor residue is now returned to the litre flask and the slow evaporation continued until the volume is reduced to 150-100 ml. The solid that now precipitates is shown to be calcium sulphate. From the hot solution this forms gypsum crystals but after standing for some days needle-shaped anhydrite crystals are deposited. At this point the solution should be filtered clear of the calcium sulphate.

The remainder of the evaporation may be conducted in an evaporating basin. The bulk is reduced to around 25 ml. During this stage it is necessary to return the evaporate to a clean beaker occasionally and to swirl it round to assist with the separation of the glistening white crystals which are now separating. The flame and silver nitrate tests show that the white crystals are common salt.

The remaining 25 ml should now be cautiously reduced to about 10 ml and filtered hot into a test tube. Crystals separate that can be shown to be magnesium sulphate. The magnesium can be shown by making a little of the salt alkaline with caustic soda solution and applying either the "magneson reagent" or the titan yellow test.

The teacher will realise that this whole series of demonstrations will have taken place over some weeks and will have occupied perhaps a quarter of an hour during the chemistry lessons. The pupils will have proceeded directly to show that sea water contains dissolved common salt. This may be done with the raw sea water or the teacher may supply each pair of pupils with three clean microscope slides. A drop of distilled, tap and sea water is placed on each of these respectively. The evaporation of the water from the drops can be effected in less than five minutes either by placing the slides on the hot plate set at "low" or "medium" heat setting or upon a black vitreolite glass plate above which there is positioned an infra red lamp of 250 watt power and internal reflector type. Visual examination of the residues is followed by dividing the sea water residue into two portions. The first portion is placed upon the loop of a clean platinum wire or iron wire drawn from a new wire gauze. The colour obtained should be compared with that got from the product of neutralising sodium hydroxide acid. These should then be compared with the colours imparted to the bunsen flame by potassium, calcium, strontium and barium salts from laboratory reagent bottles. The second portion of the evaporate is dissolved in a few ml of pure water to which a drop or two of silver nitrate solution is added.

It is also appropriate to remind the pupils that the sea is a possible source of fresh water. The growing population of the world needs ever increasing supplies of this for domestic, agricultural and industrial use. The cost of making drinking water from sea-water compared to the cost of supplying fresh water from natural sources is a cardinal factor here. Already however techniques are in operation which indicate that the cost of conversion can be brought down to the cost of supplying natural water.

The investigations and discussions have now dealt with salts from the sea and the recovery of fresh water from the sea. It is worth remembering that the bottom of the ocean has also been shown to be a vast storehouse of mineral wealth. Recent oceanographical research has revealed that the ocean floor - the bottom of the abyss - is carpeted with billions of kg of minerals and chemicals. Much of this is in the form of nodules of iron and manganese but more than forty other elements have also been identified in the nodules.

Pupils' Experiments

1. Evaporation of drops of distilled, tap and sea water on microscope slides. The pupils should suggest reasons for what they find. They can readily speculate about the various residues revealed.

2. Identification of principal salt of sea water.

   The flame test and the silver nitrate test show that the principal salt is sodium chloride. The actual testing by the pupils will be preceded by demonstration tests by the teacher, using the laboratory sodium chloride.

3. Tests to show that sodium chloride, rock salt and common salt are chemically identical.

   The pupils should carry out a series of flame tests for various elements so that they can compare these with the result for sodium. In the case of potassium the class should be shown that interference due to the possible presence of sodium can be filtered out by viewing the burner flame through a square of cobalt glass or a blue gelatine filter.

   The standard flame test is to place some concentrated hydrochloric acid in a watch glass. A mounted platinum wire is cleaned by dipping in this and applying it to the bunsen flame until the colour of this is completely unaffected. We are using the knowledge that chlorides of metals are fairly volatile salts. The clean wire is now dipped into concentrated hydrochloric acid in a second watch glass and thence into the material to be tested. It is then applied to the bunsen flame and the colour, if any, imparted is noted. The work can be accelerated if there is available a set of small glass bottles, each containing a strong solution of the various chlorides required. Each bottle stopper is fitted with a glass rod that has a short length of platinum wire fused into the end. This dips in the solution.

   A very convenient alternative to platinum wire is flame test rods. No cleaning is necessary since the end can be broken off after doing a flame test. One rod will do for a number of tests if the salt is only used at the tip.

   The flame test can also be carried out by (a) shaking the salt concerned into a bunsen flame from a salt cellar or (b) igniting solutions of the salts in dilute sulphuric acid to which alcohol has been added, in separate evaporating basins or (c) by clamping a lit bunsen burner horizontally with the open air inlet just above a petri dish containing a little zinc and dilute hydrochloric acid to which the salt to be examined has just been added.

   Finally, and as already mentioned, expensive platinum wires can be replaced by iron wires drawn from a new and unused coarse iron wire gauze. In this case the use of concentrated hydrochloric acid should be avoided. Nichrome wire can also be used.

Section 12.3 The soil environment

This has been detailed in the syllabus as an example of what can be done. So many teachers are doing other ecological studies rather than the soil that it has not been considered desirable to produce detailed guidance on this particular example of such a study.

IV References

"Minerals" - Zig-Zag Book giving colour photographs of forty-eight minerals (F Warne)

"Rocks and Minerals" - (Hamlyn)

"Minerals and Rocks" - J F Kirkaldy (Blandford Press)

"Let us collect Rocks" - a pamphlet issued free by Shell International Petroleum Company Limited

"The How and Why Wonderbook of Rocks and Minerals", N W Hyler (Transworld)

Chemistry Memoranda Nos 5 and 6 - Scottish Education Department

SECTION 13 - SUPPORT AND MOVEMENT

I Introduction

Forces cannot be seen. If we are directly involved with pushing or pulling a garden roller, or twisting a tight stopper on a bottle, we are well aware, through our sense of touch and uneasiness in the muscles concerned, that we are exerting what is called a force. It should not be difficult to associate a force with a bulldozer pushing a pile of earth around. These are, however, extreme cases and many forces exist concerning ourselves, or materials, which are not appreciated, because nothing seems to happen - the earth's force pulling us down and the tension in the string of a tennis racket, for example.

Conversely, if something is happening, forces tend to be associated with this, sometimes wrongly. The most common error is the idea that a force is required to keep an object moving. This arises either intuitively, or from observations which are restricted to cases where friction is present.

II Specific Objectives Pupils should acquire

1. knowledge of what a force does
2. the knowledge that change of motion only comes about because of an unbalanced force
3. the knowledge that friction is always a resisting force
4. knowledge of certain facts about gravity
5. the knowledge that the newton (N) is a unit of force and can be measured by a spring balance
6. the knowledge that the lever is a "force multiplier"
7. the knowledge that forces occur in pairs
8. knowledge of the joule as a unit of work 1 joule (J) = 1 newton metre (N m)
9. knowledge of the ideas of motion energy and stored energy
10. knowledge that a machine is an energy transformer but not an energy multiplier
11. knowledge of some facts about support in plants and animals
12. knowledge of some facts about muscular effort and the forearm as a lever
13. ability to build the concept of force from a set of related facts
14. ability to formulate the "law of the lever" from a set of observations
15. ability to develop a theory to explain observed phenomena (stability and leg arrangement in animals)
16. ability to apply the above knowledge to a new problem situation
17. awareness of the need to postulate ideal conditions in order to formulate satisfactory physical concepts (eg movement without friction, and ideal machines)
18. awareness that in the absence of external forces, uniform motion in a straight line is as probable as a state of rest
19. awareness of the anomalous posture of man in relation to his structure
20. awareness of the fact that any machine must waste some of the energy input

III Experimental Details

Section 13.1 Idea of Force

In this section we can establish by simple experiments and discussion the following ideas:

a. All particles of matter exert forces on each other, called gravitational forces. These forces are very small unless at least one of the objects is very large, such as the Earth. The force is always one of attraction and cannot be "switched off".

b. There are two other types of forces which act at a distance - electrostatic and magnetic. For small charged or magnetised objects, these are much greater than the gravitational forces. These forces can be repulsive or attractive.

c. All objects (animate or not) would be pulled down into a flat sheet unless there were forces between the molecules which could resist the gravitational attraction. In the case of underwater animals, or plants, the water assists in the support but would not be sufficient on its own.

d. The intermolecular forces are electrical in origin, as can be appreciated from a discussion of the composition of all matter.

e. Any particle or large object will remain at rest (or continue to move in a straight line with constant speed if already doing so) if:-

either (i) there are no forces acting on it at all - an unusual case
or (ii) there are several forces acting on it which *exactly* balance each other. They have zero resultant.

It is difficult for most children to grasp this concept - intuitively they feel that some small force must remain in order to keep an object moving.

f. Any particle or object will accelerate if acted on by:-

(i) a single force
or (ii) a set of forces which do not balance each other. Their resultant acts in the same way as a single force. (This neglects the special case where the resultant is a couple.)

Experiments to illustrate

1. Push-pull - effect on shape

Kit:- Plasticine, extension spring, compression spring, elastic bands, foam rubber, copper wire, steel wire.
Instructions:- Exert forces on the materials, using your hands or hanging or sitting weights on them.
Questions:- What happens to the materials (i) with small forces
(ii) with large forces?

What difference is there between the behaviour of the plasticine and the others?
What change, if any, must there be in the spacing of the molecules when you squeeze
(a) the rubber, (b) the compression spring (not so obvious)?

What change when you twist (a) the rubber, (b) the plasticine?

What must happen to the spacing of the molecules when you hang a heavy weight on the copper wire or the steel wire? (Safest with a box of straw under it.)

State three ways in which the shape of a piece of material can be altered by applying forces, and give the three forces a name.

In which of the above materials must the molecules exert strong forces on each other when an attempt is made to pull them apart?

Would they exert strong forces against you if you tried to push them closer together?

In which material would the forces between the molecules be weakest?

If a heavy animal could have legs made of one of these materials, which would you choose? Any disadvantages?

2. Guinea and Feather Experiment

The *hypotheses* may be forthcoming from the pupils that:

a. an object falls owing to the weight of air above it
b. an object falls owing to the magnetic force of the Earth
and c. objects always fall at different speeds, the heavier faster.

This is a good opportunity to apply scientific method in devising experiments to test these ideas.

Show a small metal disc and a feather falling in an evacuated tube. They still fall and may be seen to accelerate together. Try them or similar objects in the air - note that the air must be exerting an upward force, partly balancing the gravitational one. This air friction only acts when the object is moving. Reference can be made to Galileo's supposed experiments at Pisa.

3. Effect on motion

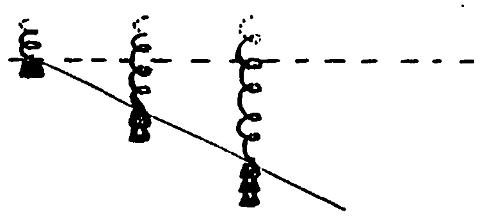
Roll a steel ball along a long corridor. How far would it go if the corridor was longer? Consider free-wheeling on a bicycle on a level road or gliding on skates. Show a vehicle moving back and forward along an accurately levelled air track, or a glass disc vibrating between rubber bands on an air table. Help the pupils to design balloon pucks and let them play with them. Bring out that moving objects continue to do so unless a force is exerted to slow them down - in the above instances there is just such a force, due to friction, but it is small and the slowing down is not very noticeable. Contrast these movements with a falling object which definitely speeds up. Here there is an unbalanced force and it causes a change in speed.

Note that in the case of the satellites, there is a single centrally directed force; and this keeps changing the direction of the motion but not the speed. The satellite moves in a circle and the force always acts at right angles to the direction of motion at any instant, hence it has no effect on the speed. (In the case of an ellipse this is not true and the speed alters.) The physics of this type of motion has proved very difficult for this age group and the topic should be left until Year III (Physics syllabus section J4). If any pupil wishes to discuss circular motion, the main point to emphasise is that, to the external observer, there is only one force acting on the object, a *centripetal* force. The difficulty lies in realising that if gravity were "switched off" a satellite would "go straight" along a tangent. Conversely, it is gravity which is forcing the body to fall from this straight path into a curve around the earth.

Measurement of force

The first worksheet in section 13 suggests pupil experiments using rubber bands or springs. In fact springs will be found to be preferable since many rubber bands do not return to their original length, even if slightly stretched.

A good link with the graphical work of the mathematics department can be established, if the pupils mark the extension of the spring as shown below.



The idea of a linear graph is then evident in a tangible way.

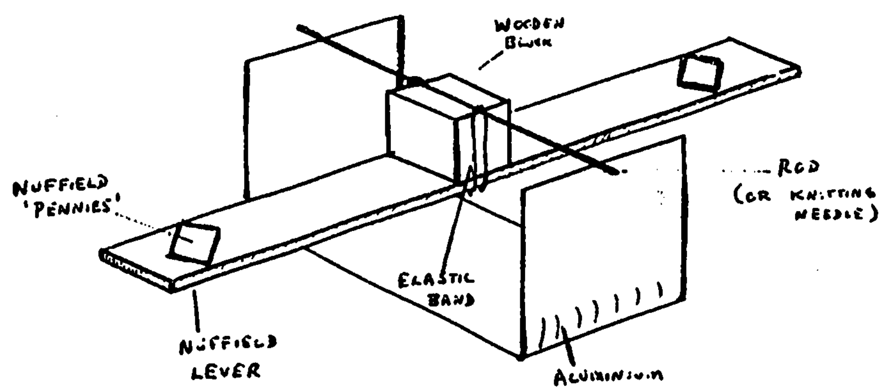
Simple balances, including the straw balance mentioned in the second worksheet, are illustrated in Physics is Fun Volume I, Chapter 8, by Jardine.

The newton, the basic unit of force, is introduced casually at this stage. Fortunately the weight of a medium-sized dessert apple is about one newton (N). This allows reference to Newton's supposed observation of the falling apple and realisation of universal gravitation.

The lever

This idea is of application in section 13.5, on Muscles.

The only difficulty in providing apparatus for these pupil experiments lies in producing stability. A SSSERC design is shown below where the Nuffield lever kit is modified to avoid this difficulty.



The rod, wooden block and lever are all held together by one elastic band.

Forces acting in pairs

Just as pupils find it difficult to accept the concept of "motion without force" (Newton I), so does the idea of "pairs of forces" (Newton III) produce confusion. This arises from the use of the word reaction when applied to two forces acting on the same body. Many of us learned our Newton's third law in the form

"to every action there is an equal and opposite reaction". This statement omitted the important point that the action and reaction act on *different* bodies. For example the Newton III reaction force to the pull of gravity on a book is the pull of the book on the Earth and this is true whether the book is at rest or falling. For young pupils it is sufficient if they realise that (a) forces occur in pairs, and that (b), in saying this, we are talking about the interaction of two objects.

The series of stations experiments suggested in the worksheet "Pairs of Forces" is designed to bring out these points. In the case of the water rocket, the compressed air exerts forces on everything it is touching. The air molecules hitting the front of the chamber (on the inside of it) push the rocket forwards. The chamber exerts a force on the air molecules and they bounce back, towards the nozzle. Any molecules hitting the sides of the chamber are compensated by molecules hitting directly opposite them. (The water enables a moderate thrust to be maintained for several seconds, instead of a very high thrust for a fraction of a second.)

This section, like satellite motion, is most topical and interesting, but it can be made difficult. It is not the intention to study the concepts involved in any detail but only to implant some fundamental ideas which help to explain some everyday phenomena.

Section 13.2 Work and Energy

As with forces, energy cannot be seen. However, it should not be too difficult to associate a loss of energy with the feeling of tiredness we experience after climbing a hill, or sawing logs. What may not be realised is that our loss of chemical energy in the muscles is an energy gain in some other form - potential energy gained in the climb, or heat energy by the saw blade and the wood, and ourselves!

We refer to the process as "doing work", but this is more generally a process of transferring energy from one place to another, often with a change in form.

In this section we should try to establish the following ideas:

a. Energy is a measurable quantity, which occurs in various forms such as potential, kinetic, heat.

b. Machines, including ourselves, can change the form in which the energy occurs.

c. During these changes, there is an overall conservation of energy. A machine cannot multiply energy, although the force can be enlarged.

d. The same unit - the joule (J) - can be used for all forms of energy.

e. The simplest method of measuring the energy transferred is by multiplying the force exerted by the distance it moves through. (newton × metre = joule)

Eg to lift an apple (weight 1 N) from the floor on to a table (1 m high) requires 1 N m (1 J) of work, so that the apple gains in P.E. by 1 J as the body expends 1 J as the body expends 1 J of energy.

Experiments to illustrote

1. Regarding work as the process of transferring energy from one system to another, compare the work done in lifting weights of 1, 2, 3 kg through a vertical height of 1, 2, 3 metres, as a thought experiment and by noting that the net result of lifting 3 kg through 2 m is the same as lifting 1 kg through 1 m six times, so that "force × distance" is a measure of the work done.

Leave a Nuffield-type "forces demonstration box" set up in the laboratory. (Nuffield Guide to Experiments II, experiment 52.)

2. Drag an object across the floor, using a spring balance. Calculate the work done. Note that this is not the same as that required to lift the object the same distance vertically. Consider walking, or cycling along a level road and up a hill.

3. Find out how much work the pupils can do in one second, by letting them climb stairs. (joules/second = watts.)

4. Use a long lever and hang a load on it. Pull the other end down slowly with a spring balance, noting the reading and also how far the load and the balance have been moved. (With a long lever they will almost move in straight lines.) Calculate the energy given to the load and the energy supplied by the balance (from the operator). Compare. The difficulty in this experiment is that the weight of the lever can complicate the issue.

5. Repeat with a block and tackle. Discuss the discrepancy between the energy supplied by the effort and that gained by the load.

6. Watch a simple pendulum move back and forward and consider when it has maximum PE, maximum KE. This is a simple device for transforming the one to the other. The value of the maximum PE can be calculated and the maximum KE taken to be the same.

Section 13.3 Support in plants

a. Support in aquatic plants

The role played by water in support can be seen by examining aquatic plants in, then out of water. With plants growing in water, the weight is partly supported by the water and so there is no need for the strength of stem which is found in land plants. If the water level falls, the plant bends over. Sticking pond weed or seaweed into plasticine and comparing with privet also in plasticine may give a good impression of this. At this stage there is no necessity for microscopic examination of supporting tissue in land plants.

b. Support in non-woody land plants

The cells in seedlings form a relatively strong structure when they are filled with water. If seedlings are removed from soil (or water), water evaporates from them and the seedlings wilt through lack of support. If after a short time the seedlings are returned to water, water re-enters the seedlings and they can be seen to "recover".

Section 13.4 Support in animals

a. Terrestrial invertebrates

As in non-woody plants, water (as body fluid) plays an important part in the support of invertebrate animals eg earthworms. By filling a sausage balloon with water the support given by the fluid is obvious. Other invertebrates eg arthropods have additional support in the form of an exo-skeleton. If the exo-skeletons of arthropods (crabs etc) are not available for examination, a model arthropod can be made by covering an inflated balloon with papier mache. If the balloon is burst after the papier mache has hardened, the shape of the model remains unchanged, thus demonstrating the support given by a firm outside covering.

b. Vertebrates

The skeleton of a land vertebrate, a head, a curved supporting column, and two girdles to which the limbs are attached, should be thought of as a firm supporting frame; that of an aquatic vertebrate as a light flexible structure. Because of buoyancy aquatic vertebrates do not need to have such strong support as terrestrial vertebrates.

The relative sizes of land and aquatic vertebrates should be compared.

Points for discussion -

1. The limb girdles in land vertebrates are larger, in proportion to the size of the skeleton, than the limb girdles of aquatic vertebrates.
2. The hip girdle in man is more massive than his shoulder girdle, whereas in a horse or dog the two sets of girdles are of similar size.
3. If a whale is removed from water it will be crushed to death by its own weight.
4. Large dinosaurs spent most of their lives standing in water.
5. Whales are able to grow bigger than land animals.
6. The hippopotamus rarely leaves water.
7. An elephant seal moves quickly in water but very slowly on land.

c. Stability

Land vertebrates are faced with a number of problems - support, movement, and stability. As well as having to support the animal the limbs must be so placed as to give stability.

Find the angle at which legs must be positioned to give greatest stability.

Kit:- Plasticine blocks (all the same weight), paper straws, thread, paper balance pans, pulley wheels attached to end of bench, weights.

Instructions:- Set four straws in each block to represent legs. Arrange straws at different angles, the thread around the centre of the body of the model, pass thread over pulley, and attach paper balance pan to the other end of the thread. Add weights to pan and compare the weights required to topple each model. (Alternatively, pull with newton balances.) Mark out and measure the area of base of each model.

Questions:-

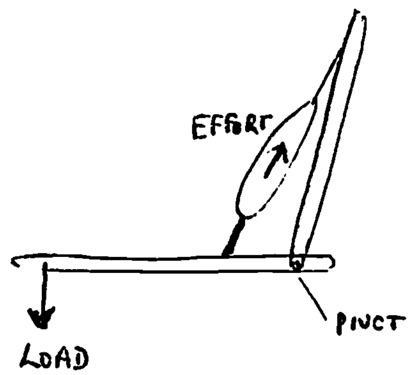
1. How are the straws arranged in the most stable model?

2. Is there any relationship between the area of base of the model and the force required to topple the model?

3. Can you adapt or modify your most stable model so that it will support twice the weight it originally held?

Section 13.5 Muscles

A simple model of the arm can be made.



The pupils should see the relationship to the earlier work on the lever, the only difficulties being that the pivot in this case is not between the two forces but at the extreme end and that in this case the effort is larger than the load.

IV References

Physics is Fun and Teachers' Guide, Volume 1, Jardine, Heinemann.

Nuffield Physics Guide to Experiments, II, Longmans-Penguin.

Nuffield Biology Teachers' Guide IV, Chapter 10, Longmans-Penguin.

See parts of Esso-Nuffield teachers' films:

Experiments in force and motion and

Kinetic Energy - introductory experiments.

SECTION 14 - TRANSPORT SYSTEMS

I Introduction

Having studied the process of digestion in Section 5.4, pupils will accept the argument that, to be of value, food taken in by the mouth must be distributed throughout the body and this is achieved only by the existence of one or more transport systems. Our knowledge of living things, however, provides a better reason for this need. Living things are composed of fundamental units - cells - which are able to function only if diffusible food molecules are brought into close proximity. For the unicellular organism no transport difficulty is presented, as molecules are simply received from the surrounding environment. Beginning with the ferns, definite systems for the transfer of water and food, vascular systems, are present in all plants. In the multi-cellular complexes of the larger animals simple diffusion is ruled out, if only on the time factor involved, and a blood vascular system has been evolved with branches extending to outlying tissues. Thus, initially, diffusible substances are transported quickly from the site of digestion to a point near enough to any cell for diffusion, thereafter, to take place normally. Educationally, this section is a good example of how classroom activities can be related to what goes on in the outside world.

II Specific Objectives Pupils should acquire

1. knowledge of some facts about foods and the means of classifying them
2. knowledge of some facts about teeth
3. some information about feeding in animals other than man
4. knowledge of some facts about the digestive system of mammalia
5. knowledge of some facts about various transport systems in plants and animals
6. knowledge of some facts about elimination and excretion in plant and animals
7. ability to apply knowledge to form classifications
8. ability to relate structure to function
9. ability to design experiments to obtain information from which to generalise, by investigating sweat secretion
10. an interest in balancing food intake to ensure good health and proper body functioning
11. an interest in maintaining healthy teeth
12. awareness of the need for water balance in maintaining healthy animals and plants
13. further skill in simple biological techniques

III Experimental Details

The contents of Section 14 fall into two parts:-

i a study is made of various forms of food, methods of feeding and the ways of getting food to the proper state and situation for digestion to occur;

ii attention is focused on the systems by which material, taken in as food and digested, is transported throughout the body and any resulting waste material removed.

Man has been selected for study as the pupils are more familiar with the structure and functions of their own bodies than of any other animal.

The problem of maintaining a proper water balance for healthy plants and animals is considered. The theory of this subject is difficult, but its practical applications are so important and striking that they should not be neglected.

Section 14.1 Type of Food: Balanced Diet

The biologist defines food as being any substance which ultimately may be broken down by an organism with an accompanying release of utilisible energy. By this definition water, although an essential substance for all forms of life, is not a food since it does not undergo changes in the same way as other matter.

One reason for eating food was provided by the work of Section 8.6 on respiration. Additionally, food is required for -

1. growth - all pupils will have weighed themselves from time to time and noted weight increases;

2. renewal and replacement of tissues - healing of wounds and replacements for the upper layers of skin which are continually being rubbed off.

A satisfactory diet must satisfy these three requirements of energy provision, growth and tissue renewal. Every food contains one or more of the three main nutrients, carbohydrates, protein and fats and may or may not have, besides, small amounts of mineral salts and vitamins. These latter assist in the growth of teeth and bones and in the regulation of body processes. Information on the classification of food types is available in many Science textbooks. Pupils should be encouraged to understand the importance of a balanced diet and to think about the availability and suitability of food and diet in different parts of the world.

Various classes of food-stuffs are readily distinguished by the application of simple chemical tests:

Starch A few drops of "iodine solution" (aqueous solution of iodine and potassium iodide) are added to the substance under test and a characteristic dark blue colour indicates the presence of starch. This is a very sensitive test.

Reducing sugars

The sugar under test is heated to boiling point with a few millilitres of Benedict's solution in a test tube. The solution will change from clear blue to opaque green, yellow, and finally a brick-red precipitate of cuprous oxide will appear. Beware of "bumping" in the test tube. "Clinistix" test paper is a very convenient test for glucose but not for other reducing sugars. Dip the treated end into the solution obtained after shaking up the powdered substance with cold water. Glucose is present if the test paper becomes blue within one minute.

If someone wishes to test sucrose it will be necessary first of all to hydrolyse it by boiling with dilute hydrochloric acid and neutralising with caustic soda solution.

Fats Any food which leaves greasy marks on paper is likely to contain some fat.

A really sensitive test can be performed using ethanol. Pipette or "syringe" about 2 millilitres of ethanol into a test tube and add the material to be tested. Shake the mixture. Allow any solid matter to settle and pour off the ethanol into a second test tube. Now add about 2 millilitres of cold water to the decanted ethanol and the presence of fat will be shown by the liquid turning milky in appearance.

Proteins Millon's Reagent is used for this test. About 2 millilitres of Millon's Reagent is added to a small quantity of the materials (cut up fine, in suspension or in solution) under test and the whole lot heated gently in a test tube. The formation of a coagulated deep red mass indicates the presence of protein.

"Albustix" test paper can be used instead of Millon's Reagent. Dip the treated end of the test paper in the solution which, in the case of solid material, has to be obtained by boiling for a few minutes in water and cooling. Protein is present if the test paper turns green immediately. The shade of green depends on the concentration.

All the above mentioned tests are well within the scope of pupils at this stage, working in small groups or even pairs. Before commencing to test random samples of food stuffs, preferably brought in by the pupils themselves, the specificity of each test will have to be established and this might be done as a demonstration, remembering to include a "control", water for example. It is always well worthwhile to arrange for class results to be tabulated.

An important result from these tests is to confirm the composite nature of many foodstuffs, milk and wheat flour providing excellent examples of this. The gluten and the starch in the flour are easily separated by putting about a teaspoonful into a square of clean cotton cloth, gathering up the corners and kneading the whole lot with the fingers under water. The operation may take 5 or 6 minutes and at the end of that time a sticky residue, drying to a stringy solid, is left on the cloth. This consists largely of gluten.

So sensitive is the ethanol test for fats that it will work most satisfactorily on thin shavings of nuts (use a razor blade) and on cooked foods, biscuits and cakes. The food colours are not dissolved in the ethanol, and so the milkiness is not masked by extraneous colours.

There are many excellent food charts, often in colour, which will serve to complement much of what is done.

Section 14.2 Teeth

This can easily become an extended study in odontology, and teaching should follow the Explanatory Notes and Practical Work.

To break down solid food on the change-over from a liquid diet mammals grow two successive sets of teeth. In man, the first set, numbering 20 and known as deciduous or milk teeth, is fully formed at approximately two years of age. By seven years of age individual teeth are being replaced by those of the permanent set, eventually numbering 32, and generally not complete until the early twenties.

In both sets, our teeth are structurally similar, as may be demonstrated by sawing teeth in half, longitudinally, and smoothing off the cut surfaces. It is appreciated that teeth are not always readily to hand for this sort of work and recourse will have to be made to coloured charts of teeth in section. There is no difficulty in obtaining these - General Dental Council, 37 Wimpole Street, London W1 supplies them free. Using outline rubber stamp diagrams pupils will gain a fair understanding of tooth structure. Tooth modelling in papier maché is also worth trying.

Most of the pupils will be familiar with having a tooth stopped and might be asked how the dentist practises simple physics to eliminate pain following a tooth filling. He must interpose a non-conductor of heat between the metallic filling and the dentine to prevent hot food in the mouth from stimulating the nerves as a result of heat conduction. A free coloured chart illustrating the technique can be obtained from Oral Hygiene Service, Hesketh House, Portman Square, London SW1.

The teeth of mammals are of four kinds, incisors, canines, pre-molars and molars.

1. Incisors are cutting teeth found at the front of the mouth and possess sharp chisel-like crowns.
2. Canines flank the incisors and are easily distinguished by their large pointed crowns, ideal for gripping and tearing.
3.) Pre-molars and molars are the back teeth. Their quadrangular shaped uneven crowns identify
4.) them as cutting and grinding teeth so designed to divide up the food into smaller pieces once it has been taken into the mouth. Molars are not present in the first set of teeth.

Comparison can be made between the jaws and teeth of a cow or sheep (vegetarian): cat or dog (carnivore): man (omnivore). Observation on the feeding and habits of farm animals and domestic pets can provide the answers to - which animals chew food and which swallow it in lumps? These habits can be related to the form of the jaw and structure of individual teeth. If a dog is studied, it is most noticeable that the cutting and crushing are done by molars and two pairs of large pre-molars working with a scissors-like action, and as soon as the pieces are small enough for swallowing they are immediately gulped. The other pre-molars take little part in these actions and in consequence are comparatively small and show no specialisation. Their function, probably, is to help hold the prey once it is caught. Grooming is done with the front teeth, the incisors, and as would be expected they are small and quite capable of picking up, or nipping, small objects.

Molar shape has a determining effect on jaw action. The absence of chewing in the carnivore has resulted in one of the back teeth on both sides of each jaw becoming very large and strong and meeting top and bottom like the blades of scissors. Jaw action, therefore, is straight up and down. Herbivores differ in their jaw actions. Low ridges across the crown of the molars at right angles to the line of the jaw in a rabbit are responsible for a backwards and forwards motion. The side to side jaw motion of the sheep is brought about by crescent-shaped ridges on the molar crowns which follow the line of the jaw making for increased efficiency in grinding the food. Jaw action in omnivores, not unexpectedly, covers both forwards and sideways actions, but the latter effect is reduced to produce crushing rather than grinding.

With the herbivore there is no prey to be killed and understandably the canines are absent or very much reduced. But the vegetation to be consumed can be very tough and teeth must be provided for cutting and grinding it very finely. Thus, in the herbivore, the incisors, pre-molars and molars are all very well developed. Typical of herbivore dentition is a gap between the incisors and the pre-molars called the diastema, the function of which is to provide space to hold food cut by the incisors. Ask the pupils to watch carefully for the grass protruding from a cow's mouth when it is disturbed feeding in a field. The grass is being held in the diastema.

The rabbit is an example of a special type of herbivore, the rodents, characterised by continuous growth of the incisors. All will know the feeding action of a rodent, but has the usefulness of the split lip adaptation been noticed?

If complete skulls are available of the animals under study, pupils will have the opportunity to note these differences in molar shape for themselves.

The subject of tooth care can be introduced by means of a demonstration. A tooth, except for a small area, is coated with wax and immersed in weak hydrochloric acid for a few days, when it will be noted that the acid has had a deleterious effect on the tooth. From this it is deduced that, if acid conditions prevail in the mouth, tooth decay must be expected. The next step is to investigate how such conditions arise and it will be necessary to call for volunteers who, it is assumed, cleaned their teeth before coming to school and in the interval have eaten nothing. Half of the volunteers are asked to rinse their mouths with one per cent glucose solution and after the lapse of a few minutes the front teeth of all are painted with 0.02 per cent *aqueous* methyl red dye which, where acid is present, will turn from its original yellow to red. Acid in the mouth is produced by the microflora acting on food lodged in the crevices of the teeth and therefore any action such as cleaning the teeth after meals, chewing an apple or raw carrot or refraining from eating between meals will reduce the amount of acid formed and help prevent decay. The change from alkaline, the normal state of the mouth, to acid conditions over a 12 hour period during which breakfast, dinner and tea are consumed is very well illustrated in the chart referred to earlier produced by Oral Hygiene Service. Unilever has also made a film on this subject entitled "Where there's a Will," which may be obtained on free loan. It is thoroughly recommended for showing to pupils.

No discussion on tooth care can, these days, omit reference to fluoridation. This, however, has become such a controversial issue that guidance on this topic should be obtained by reference to the pamphlets issued by the Ministry of Health and the British Dental Association.

Section 14.3 Other Methods of Feeding

There is scope here for developing a sequence from a field-trip to keeping collected specimens alive under semi-natural conditions in the laboratory and using these animals as the models in a biological study. Any animals will do, depending on the naturalist interest of the teacher and the type of environment. The freshwater mussel is mentioned in Curriculum Paper 7 and it is not difficult to keep alive in an aquarium. It should always be given some sand on the tank bottom, in which it can bury its "food". It will then hold its body sloping obliquely up, with the front end close to the ground and the hind end much higher and with the inhalent and exhalent apertures, *siphons*, open for the passage of water in and out. It will take in and digest any small particles of dead organic matter that may be floating in the water. To provide it with fresh microscopic food a bunch of fresh pond weed should sometimes be dipped into the surface water and shaken.

The water currents will be made visible if a *small amount* of mud is added to the water. A current of water will be seen passing into the animal through the larger siphon while through the smaller a water current is passing out.

Section 14.4 Digestive System

This is a well documented aspect of biology and there is plenty of information available.

It is important to avoid all unnecessary details in describing the digestive system and digestion. The essentials are:

i *In the mouth*, the mastication of food and the action of alkaline saliva.

ii *In the stomach*, the churning of food and the action of acid juices.

iii *In the small intestine*, the action of alkaline juices and the slow passage of digested food through the tube walls to the "outside".

The parts played in digestion by the liver and pancreas should be studied.

Chemical analogies may be drawn between the digestive process, the dissolving of mineral salts and the ideas of neutralization.

The examination of a dissected mammal is merely to emphasize the layout of the main organs of digestion.

Section 14.5 Need for a Transport System

This section deals with the "problem of digestion" - the fact that food may be within the gut but still outside the body because it is separated by the gut wall from the body tissues where it is needed.

Teachers not familiar with the biological processes involved should consult a biology textbook before teaching this section. In *"Biology by Inquiry"*, *Book II, Chapters 7 and 8*, this section is fully explained. The contents of these chapters are above the level of SII and the teacher should consider them as background knowledge on which to base his approach to this work.

Section 14.6 Types of Transport System

This is very much a biologist's section and individual biologists may find it difficult to restrain the depth of their teaching - the underlying theory can be difficult and teachers should be wary of venturing into details of osmotic action with SII pupils.

There are *three* types of transport or circulatory systems: (1) the *simple type* as in amoeba, canadian pond weed and hydra; (2) the *open type* as in plants and the crayfish; and (3) the *closed type* as in the earthworm and the higher animals.

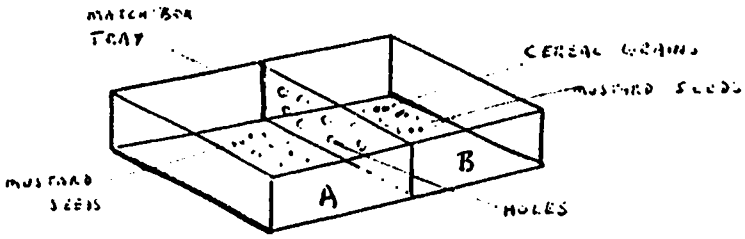
The problem of water loss and gain can literally be put in measurable quantities - the average person swallows about 500 kg of liquids in a year and could not do without it. A man can live without food for weeks but only a few days without water.

Why do we drink? The simple answer is that we drink because we are fishy creatures. The earliest forms of life flourished in the sea and primitive one-celled creatures floated in an agreeably constant environment which provided a constant supply of oxygen, food and an efficient waste disposal system. The first dry land creatures did not entirely escape from the marine environment for they merely continued to carry the sea around with them, internally, for blood is a near relation of sea water and performs all the functions of the original medium where life began.

In man, no less than in fish or tadpole, it is important for the composition of the blood to be correctly maintained. The sensation of thirst is a reminder that the fluid level of the body needs to be topped up to restore losses in breathing and perspiration and in diluting some of the waste products of digestion so that the kidneys can dispose of them.

Many important biological processes depend on the passage of water through the boundaries separating a dilute solution from a concentrated solution. Membranes of living cells are capable of restricting or allowing the passage of substances. This control depends partly on the sizes of the molecules separated by the membranes, and for this reason such a membrane can be described as *selectively permeable*.

The two-way flow through a membrane can be illustrated and in some measure explained by using a model.



In side A: mustard seeds in large numbers represent water molecules.

In side B: mustard seeds represent water molecules; the cereal grains represent the sugar molecules in the solution.

Replace tray in its cover and shake it to and fro for a few moments. Then remove the tray and observe.

If it were not for a biological device like this, in conjunction with our waterproof skin, we should shrivel in the sea and burst in the bath.

Details on 14.6 (a), (c) and (d) are readily available and earlier reference was made to "Biology by Inquiry" Book II, Chapter 8. The observation of streaming in plants and single-celled organisms [14.6 (b)] is not difficult if a correct choice of organisms is made, and the unicellular organisms should be slowed down, using strands of cotton wool or "Polycell" (the latter made up 50:50 with water and diluted as necessary). The addition of Congo Red as suggested in Curriculum Paper 7 may inhibit movements within the cell.

Large species of *Paramecium* such as *P. candatum* should be ordered for this work. The canadian pond weed leaves should be taken from near the top of an actively growing shoot in a pond or acquarium. Streaming may be speeded up by raising the temperature of the water from which the leaves are taken.

Section 14.7 and 14.8 Body Waste; Excretion

Curriculum Paper 7 gives two approaches to this section based on traditional biology teaching, but Clarke et al in *"Biology by Inquiry" Chapter 10* bases a teaching approach on *The internal environment* and this provides a logical development from the problem of water loss and gain. The approach in "BBI" is again above the level of SII but teachers might well consider the benefit of introducing these young pupils to the biological ideas of *homeostasis*.

The main teaching difficulties will be in the structure and function of (I) the kidney and (II) the skin. A latex injection of a fresh kidney is a skilled job, using a pressure apparatus. The kidney, after injection, is placed in a bath of acid formalin or dilute acid to harden the latex. An excellent feature of this method is the elasticity conferred upon the parts injected which can be stretched aside for dissection of underlying structures. However, the dissection of a fresh kidney is not difficult. Use a large kidney, eg pig or a sheep, obtained from the butcher. It is necessary to make sure that the renal artery and vein, and also the ureter, are not cut off too short. Hold the kidney in the left hand with the *hilos* (a cleft near the centre of the concave side where the renal artery and renal vein enter the kidney) pointing downwards. Using a sharp scalpel cut boldly round the edge of the convex side. Stop short at the blood-vessels and ureter. Open the kidney like a book. Rinse the cut surface with water and then examine the kidney tissue. The cortical and medullary regions can be made out quite easily. Use a seeker to trace the ureter inwards into the pelvis.

The skin performs important functions in the process of excretion. It may excrete about 600 ml of water during an ordinary day; on a hot day it may excrete as much as 2,000 to 3,000 ml. But in spite of this apparently great amount of water the total solids excreted by the skin are not very great. It is to be borne in mind that the chief function of the sweat is to keep the body cool. If the water is not needed for this purpose it is not secreted from the blood by the sweat glands; excess water in the body is eliminated by the kidneys.

The liver is concerned with the destruction of red blood corpuscles and the products of these destroyed red cells form a large part of the bile that is formed in the liver. This is an interesting example of a waste product that performs a useful function in aiding in the absorption of fats.

Plants do not possess well developed excretory systems such as occur in animals. Wastes in plants may be eliminated by diffusion from roots or by secretions from surface glands. The dropping of various parts like bark, leaves and twigs disposes of certain wastes. The general subject of water loss from plants involves *guttation*. This is not to be confused with *transpiration*, which is giving off water in the form of vapour. In guttation, the water is exuded from special structures connected with the transport system. The drops lie along the edges of leaves and are sometimes mistaken for dew.

Bird pellets Most of the flesh-eating birds have a special way of separating the flesh from the fur, bone, shell, scales and other indigestible matter. Instead of wasting time separating it as they feed they swallow it all. After a time the meaty part is digested and the unwanted parts are rolled into an egg-shaped mass and regurgitated. These rejected remains of food are called pellets and by careful examination can give an exact idea of what has been eaten.

IV References

"Biology by Inquiry" and Teachers' Guide Book II Heinemann.

Note

Section 15 Electricity and Magnetism

The notes on this section are included with those on Section 7, Electricity, in the Memorandum on Year I.